METAL PROGRESS

MAY, 1941   Vol. 39 No. 5

TABLE OF CONTENTS

The Zinc Situation 557
by Ernest E. Thum

Controlled Atmosphere Generators; Recent Advances in Equipment . 560
by E. E. Slowter and B. W. Gonser

Chromium Steel for Ball Bearings; Inspection and Heat Treatment .. 567
by Alfred S. Jameson

Zay Jeffries 574
A biographical appreciation by S. L. Hoyt

"Quick, Watson, the Micro!" (Examples of Metal Detection) 577
by R. M. Brick

Table of Lattice Constants 580
by H. S. Rawdon

Cracks in Fillet Welds 580
by E. Helin; (Abstract of Engineering Foundation's Translation of "Sprekker i Kilsveiser og Deres Arsaker", *Teknisk Ukeblad*, Vol. 87, p. 289, 1940)

Crystallography of the Chemical Elements (Data Sheet) 581
by William Hume-Rothery; revised by H. C. Vacher

Critical Points, by the Editor 583
Ballistic Researches at Frankford Arsenal
Sub-Visual Defects in Aluminum
Welding of Hulls, Armor, Aircraft
Anti-Fouling Device for Electrodes
Who Envies Whom?

Impact and Hardness Tests; Notes on Their Practical Use 585
by Gordon T. Williams

Openhearth Conference 592
by John G. Dun

Personal News, Largely Movements of ASMembers 596, 598

Fatigue Data Used in Design 604
by E. C. Hartmann and R. L. Templin; (Abstracted from two articles: "Fatigue Test Results, Their Use in Design Calculations", by E. C. Hartmann, *Product Engineering*, Feb. 1941; and "Fatigue Machines for Testing Structural Units", by R. L. Templin, *Proceedings*, A.S.T.M., Vol. 39, 1939.)

The Defense Program 618
by William S. Knudsen; (Excerpts from an address to Military Order, Veterans of Foreign Wars, April 5, 1941.)

Properties of Quenching Oils 632
by J. A. Jones and W. W. Stevenson; (Abstract from Second Report of the Alloy Steels Research Committee to the British Iron & Steel Institute, 1939, p. 269.)

Literature, Produced by Advertisers, Free to Readers 543, 544, 545

Index of Firms That Are Advertising 658

Published monthly and copyrighted, 1941, by American Society for Metals, *7301 Euclid Ave., Cleveland, Ohio. Subscriptions $5 a year in U. S. and Canada (foreign, $7.50); current copies $1; special reference issues $2. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, under the Act of March 3, 1879 . . .* The American Society for Metals *is not responsible for statements or opinions printed in this publication. The Editor is sponsor for unsigned and staff articles.*

Owned and Published by
THE AMERICAN SOCIETY for METALS

A TIGHT SITUATION IN ZINC

By the Editor

ESSENTIAL metals of a war with machines are at least three: Steel for ships, guns, armor, armaments, projectiles and engines; aluminum for aircraft; brass for cartridge cases. Of steel the United States is the world's largest producer. Of aluminum we have not enough, but new capacity is coming in rapidly. Brass for cartridge cases requires both copper and high grade zinc, and its present and prospective supply was examined at the annual meeting of the American Zinc Institute in St. Louis late in April.

Cartridge brass looms large in the zinc industry's mind because its manufacture in peace times is relatively small. Zinc and copper requirements are readily figured, however, once the military men fix their ammunition schedules, allocating it according to the speed at which the shell, powder and loading plants can be built. For example, JOHN A. CHURCH, consultant on copper and zinc in the Office of Production Management, stated that by the middle of 1942 cartridge brass will require more zinc than any other single purpose — and consume at a rate about 100,000 tons per year *more* than is at present going into this item. This means high grade zinc, low in impurities, of which in 1940 we made about 295,000 tons; consequently, by mid-1942 we must be producing this somewhat special metal at the rate of 400,000 tons yearly, or else restrict other consumers of this grade severely. Assuming, as is true, that the necessary ore is at hand, where will this high grade metal come from?

The two Montana electrolytic plants at Great Falls and Anaconda are about to increase their capacities 8% by utilizing excess voltage available in their generators; this will give 12,000 tons more per year. The new electrolytic refinery at East St. Louis, just starting, has a capacity of 17,000 tons. The American Smelting & Refining Co. is breaking ground for a 24,000-ton refinery at Corpus Christi, Texas, and this will be ready by mid-1942 (if the power plant can be built). Altogether we see 53,000 tons more annual capacity in electrolytic metal within 15 months; add the predictable increase in high grade from New Jersey (another 18,000 tons) and we have an apparent shortage of 39,000 tons annually which must come from redistilled lower grades of metal, or curtailed use of die castings which have recently been consuming high grade zinc at the rate of about 150,000 tons per year. (The automotive industry has already been asked to eliminate 25% of the die castings in future models — the super-duper brilliant heavy hardware on 1941-model front-ends will soon be missing!)

The above is for the Army's requirements for cartridge brass as now envisaged.

But, as Mr. CHURCH pointed out, not all items requiring zinc are as readily classifiable as cartridge brass and gilding metal for bullet jackets, rolled zinc for powder containers, galvanized siding and roofing for cantonments, or the galvanized plates and pipe for ships. Take the matter of pole-line hardware; who is to say how soon a new communications system is to be used as an essential link in national defense? No government official has been able to estimate the total *requirements* for zinc, but Mr. CHURCH has arrived at the conclusion that "there is now and there will be sufficient zinc for all defense purposes (the identifiable military requirements) and also enough for all the essential needs of the basic national economy." In the next sentence, however, he warned that many consumer demands would perforce remain unsatisfied.

Already there is a shortage, and therefore a system of priorities wherein, month by month, each zinc producer is required to set aside a stipulated percentage of his current metal into a "kitty" subject to direct control of the Priori-

ties Division of the OPM. In April this proportion was 5%; in May 17%. This indicates the trend. While large, well-established producers with forward contracts have had little difficulty in getting sufficient zinc, the defense effort has worked on down through subcontracts into a multitude of smaller plants, and their unforeseen requirements as well as England's — already expanded many fold — have to be taken care of by shipments from the "kitty".

Smelter Capacity

On the basis that our *exact* requirements are unknown and unpredictable, but will certainly absorb every pound of metal we can lay our hands on, what plans have been made by the smelters and refiners to meet the situation? Howard I. Young, president of American Zinc, Lead & Smelting Co., presented a summary of this situation to the Institute and from this an estimate may be made of the way the metal will be allocated during the next year.

The last reliable statistics for foreign zinc production are for 1939, as follows, expressed in short tons of metal:

	1939	1940
North America	775,000	926,000
United Kingdom	148,000	175,000
French Indo-China	6,000	?
Japan	60,000	80,000
Russia	100,000	?
Axis-Controlled Countries	760,000	?
World total	1,849,000	?

The 1940 figure for Axis-controlled countries is probably no more than 1939, for smelters in Belgium, Netherlands and Norway (producing 275,000 tons of zinc in 1939) used transoceanic ore almost exclusively, and this has been entirely shut off by the blockade. Mine output in Germany, Poland and Yugoslavia has doubtless been expanded to take care of this deficit as far as possible; at any rate, Germany is self-sufficient in zinc — so much so that new zinc alloys are replacing alloys of the scarce copper on a great scale in Europe today.

Of the 1940 figures for North America 724,000 tons of zinc were smelted and refined from ore and secondary metal in the United States, and the operating rate in December was at approximately 780,000 tons per year. Of this metal 195,119 tons or 27% was Special High Grade, 98,940 tons or 14% was Grade A (High Grade), 65,321 tons or 9% Grade B (Intermediate), 80,681 tons or 11% Grade C (Brass and Select), and 284,131 tons or 39% Grade E (Prime Western).

Figures for 1941 and 1942 were predicted by Mr. Young on the basis that every effort would be made to get maximum production from existing capacity and from new units that are already under construction or planned. His figures follow, and to them have been added 16,000 tons from galvanizing drosses reworked in large graphite retorts:

	1940	1941	1942
United States	724,000	906,000	956,000
Canada and Mexico	202,000	255,000	282,000
British Empire (less Canada)	175,000	177,000	224,000
Total	1,101,000	1,338,000	1,462,000

The anticipated expansion in electrolytic zinc in these years (included in the above figures) has already been listed. The balance will come from new retorts in existing zinc smelters.

Mr. Church gave some idea of the requirements for cartridge cases. Mr. Young attempted an estimate of civilian and export demands. What the civilians might expect, at the worst, may be gaged from the statement that in England, where "normal" consumption is on the order of 225,000 tons yearly, less than 50,000 tons went into non-defense items in 1940 — a curtailment of about 80%! Very large exports to England late in 1940 licked up most of the visible stock of metal in the United States. Since Canada and Australia have themselves an expanded munitions program, England cannot get large increases over her normal imports from them, yet she is currently using zinc at the rate of about 325,000 tons per year. Assuming that England will be able to produce at her current rate, she will require much from us, and Mr. Young believes that England, China and South America will need at least 100,000 tons of our zinc metal in 1941, and this figure for exports will probably be 150,000 in 1942.

Estimates of 1941 demands are therefore:

Export	100,000 tons
Brass	300,000
Galvanizing	250,000
Die Castings	125,000
Rolled Sheet	55,000
Miscellaneous	35,000
Contingencies	70,000
Total	935,000 tons

This appears to be about 50,000 tons more than our maximum expectations for smelter and

refinery production, and the shortage for 1941 is about 10% of the "normal" civilian demand in the United States (540,000 tons average consumption, 1935 to 1939 inclusive). Visible stocks, on April 1, 1941, of slab zinc, in smelters, were 13,000 tons, plus 67,000 tons on consumers' shelves, so we will have to get along on what we make — augmented probably by 25,000 to 35,000 tons of metal from the Rosita smelter in Mexico. However, the situation might get worse at any moment if some intensive air raids should knock out the principal English smelter.

Ore Supply

Since important mines in various parts of the world have been mining more ore than they could ship overseas or smelt and sell locally, there has been a gradual increase in stocks of ore (concentrates) above ground for the last couple of years. This situation has been further aggravated by total blockade of European smelters, which otherwise would be large importers of concentrates. American producers, who ship and smelt as fast as they mine and concentrate, are therefore fearful of the effect of this overhanging stock, measured in hundreds of thousands of tons, as soon as it can be shipped freely, or forced into distress sales. However, at the present time, bottoms are so scarce and freight rates are so high that we even lack the comfortable assurance that ample zinc ore will reach our own reduction plants. Curtailment of intercoastal shipping has, for instance, raised the charter rates from Mexico to North Atlantic ports from $4.00 per ton as of February 1941 to $9.00 as of May 1. (Mexican railroads are so deteriorated that they cannot respond to any overload.) Argentine ore costs $16.00 per ton to bring up. Canadian concentrates are now reaching our inland smelters by rail from British Columbia, Quebec and Newfoundland.

Elmer W. Pehrson of the U. S. Bureau of Mines was able to give a picture of the American mining situation, the result of a survey made as late as January. This investigation indicated that 711,000 tons of recoverable zinc will be had from American ores in 1941, an increase of 7% over 1940, and a figure checked by a 690,000-ton rate for December, January and February. Of this, ore containing 100,000 tons of extractable metal would ordinarily be used to manufacture oxide for the paint and rubber industry, but an addition of 66,000 tons of metal will be had from re-treatment of scrap and drosses. In view of the fact that we can make approximately 906,000 tons of metal in retort and electrolytic plants in the United States, it is apparent that 450,000 tons of foreign ore containing 226,000 tons of extractable zinc must be imported. Almost exactly this amount of ore actually existed in smelter inventories on March 1, 1941, so that imports during the rest of the year will be surplus against unforeseen losses in American production or against 1942 needs. Smelters have already reported unfilled contracts for delivery in 1941 of 288,000 tons of foreign ore containing 135,000 tons of recoverable metal, and delivery of this is reasonably sure.

No rapid expansion in American production, paralleling the 70% increase during the 1914-18 war, can be expected because the economic circumstances of the last decade have prevented venturesome capital from prospecting new areas, developing reserves in existing mines, or increasing ore treatment facilities. Due to the high value of American exchange, foreign zinc can be profitably made in great quantities at 3¢ of our money per lb. Add 1.4¢ tariff and the expected selling price in a free market will be 4.4¢ (plus freight), which is not enough to pay for much American zinc now being produced, nor attractive to newcomers as a long-time prospect. In other words, American mines will be hard put to maintain their present near-maximum rate of production due to lack of developed reserves, reduction facilities, and enough skilled and contented labor.

Informal opinion was that 9 or 10¢ per lb. of zinc, instead of the present selling price of 7.25¢, would be necessary to expand mine output to any considerable degree. Such a price would also largely increase the recovery of zinc from scrap, from old smelter slags, and bring into range the 60 million tons of tailings in the Joplin district, which contain 0.4% recoverable zinc (120,000 tons of metal).

Summary

What official and expert opinion sums up to is this: At present prices we will have enough zinc for defense requirements in 1941 and 1942, but sea lanes must be kept open and bottoms secured for importing 40,000 to 50,000 tons of concentrates per month, and nothing must be permitted to interfere with domestic mining and smelting. Even so, civilian supplies must be cut at least 10% in 1941 and probably three times as much in 1942.

CONTROLLED ATMOSPHERE GENERATORS; RECENT ADVANCES IN EQUIPMENT

By E. E. Slowter
Chemical Engineer
and B. W. Gonser
Metallurgist
Battelle Memorial Institute
Columbus, Ohio

FIVE OR SIX years ago the use of controlled furnace atmospheres had become fairly well established for the protection of low and medium carbon steels. Partly burned gases were commonly used although both experimental research and plant operation proved that they were unsuitable for hardening of high carbon and special alloy steels without soft skin (decarburization). The value of a completely inert atmosphere, such as pure nitrogen, was known but no commercial equipment was available for its production. Atmospheres of carbon monoxide and nitrogen had also been shown to be desirable in experimental work but production equipment was unavailable. Other special atmospheres, such as those from cracked natural gas and cracked ammonia, were actually in use but there was no great amount of information on their capabilities, and installations were comparatively few. Reference to a correlated abstract of that time made by H. W. GILLETT in *Metals and Alloys* will verify the paucity of real information available in 1935.

The control of atmospheres at that time usually was by adjustment of air and gas flows. Analyses were commonly made by a simple Orsat apparatus which did not show the water vapor, methane or hydrogen. Occasionally indicating or recording carbon dioxide meters, borrowed from boiler plant practice, were used to show the atmosphere analysis but these left much to be desired in knowledge of the complete gas composition.

Since that time a tremendous amount of work has been done in the laboratory and in industrial plants to give a clearer picture of the results to be obtained by the use of controlled furnace atmospheres and to show the best type of atmosphere for any given case. New uses outside the metal treating field have been developed. Existing types of equipment have been improved and refined and new types have been developed. The present authors prepared an account of "Instruments for Control and Analysis of Controlled Atmospheres" in METAL PROGRESS for last October (page 555) and they will now describe the broad principles on which are based new apparatus for atmosphere production incorporated into commercially available devices. There is no intention of comparing competing devices, and hence, although several companies may make gas producers operating on the same basic principles, only one modification will be described.

Nitrogen Atmospheres

One notable advance is the development of apparatus for the production of nitrogen atmospheres. The advantages of atmospheres based on nitrogen were early known but the development of a satisfactory nitrogen generator had to await dependable and efficient combustion control and carbon dioxide scrubbing equipment.

Nitrogen generators may be made in a complete unit where a fuel gas is completely burned with the proper air mixture and the H_2O and CO_2 subsequently removed from the product gas, or they may consist of separate units, one of which produces the burned gas and the others remove the H_2O and CO_2. A flow sheet of a complete unit (Mahr Mfg. Co.) system is shown in Fig. 1. In it a fuel gas and air are mixed in the desired proportions with precision control valves. The mixture is burned in a refractory lined, non-catalytic, combustion chamber producing an atmosphere consisting essentially of N_2, CO_2 and H_2O at 2350° to 2500° F. Small (or even relatively large) amounts of CO and H_2 may be present when the apparatus is operated on the reducing side of complete combustion, while O_2 may be present if on the oxidizing side. The hot products then pass through a heat exchanger; the cooling medium is air from the main blower. (The exhaust of heated air is used in reactivation of the alumina driers.) The partially cooled combustion products then enter a tubular condenser which cools them to 85° F. or lower, which removes the bulk of the water vapor. The condensed water is removed through a water-sealed trap.

The gas then passes to a CO_2 scrubber — a motor driven gas diffuser immersed in a liquid absorbent. Gas enters at the bottom through a manifold. A perforated spinner is suspended directly over the manifold, breaks up the gas bubbles into very small size, and gives a swirling action to the absorbent which increases the CO_2-scrubbing action. By the time the gas reaches the top of the liquid it is free of CO_2. From the scrubber the gas passes through a combination condenser, trap and cooler which removes any entrapped absorbent. This device is followed by a dual-unit activated alumina drier which removes water vapor down to a dew point of −45 to −60° C. The product can easily be made in the same purity as cylinder nitrogen.

The absorbent is a 20% aqueous solution of mono-ethanolamine used under the Girbitol patents and licensed by the Girdler Corp. of Louisville, Ky. The CO_2-containing absorbent is passed through a heat exchanger to preheat it before it reaches the reactivating boiler, wherein CO_2 is driven off by heat. Regenerated absorbent is then pumped back through the heat exchanger and cooler to the scrubbing tower.

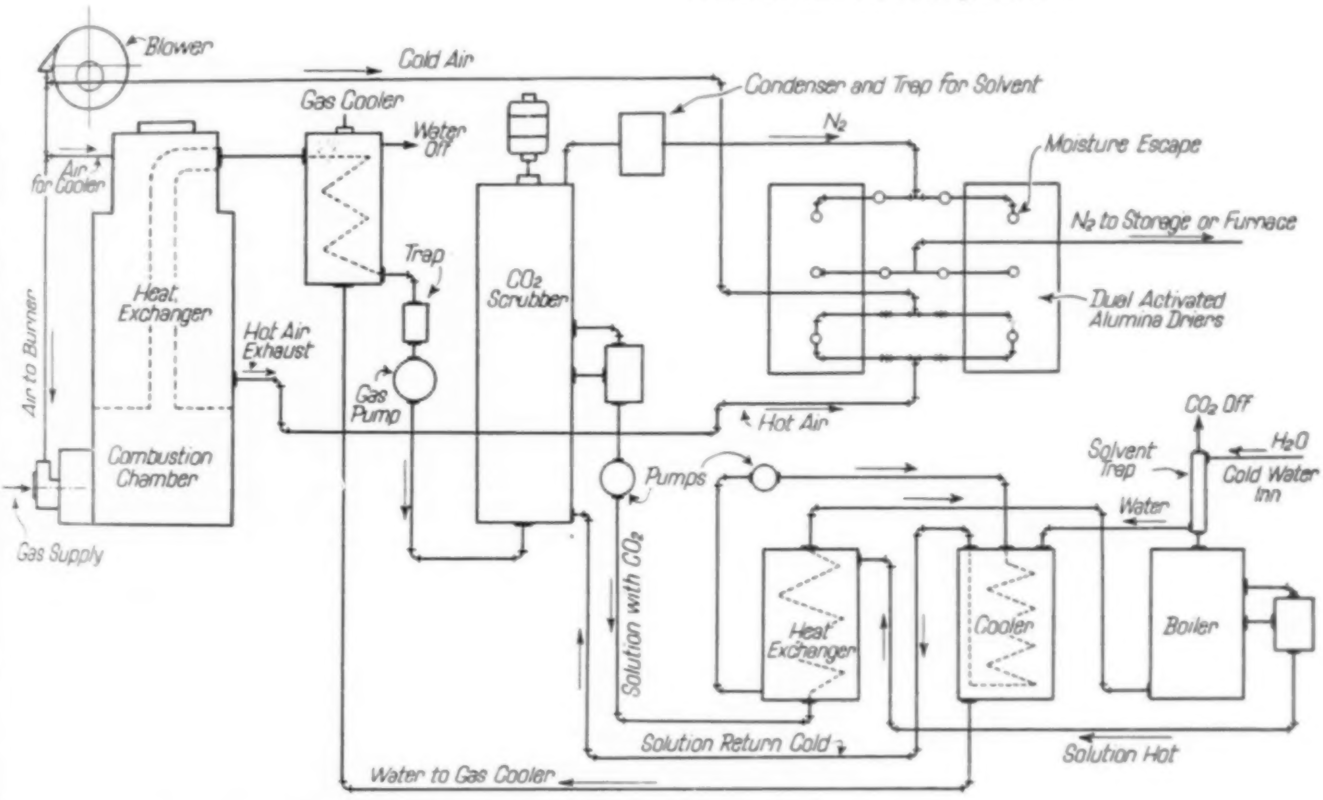


Fig. 1 — Flow Sheet of Nitrogen Generator, Purifier and Solvent Regenerator (Mahr Mfg. Co.)

It is claimed that, with natural gas at 50¢ per 1000 cu.ft., power at 1¢ per kw-hr. and cooling water at normal industrial rates, dry nitrogen (free of CO_2) may be produced for 27¢ per 1000 cu.ft. This cost includes gas burned under the reactivating boiler and alumina driers, power for the combustion blower, the gas booster, the CO_2 scrubber and the solution pumps, but not depreciation, as this is a varying item with each company.

The CO_2 scrubbing units may also be used

with existing equipment, making partly burned gas atmospheres, to remove CO_2 from mixtures of H_2, CO and N_2. In one unitary system of this type produced by Westinghouse Electric & Mfg. Co., equipment is available in capacities of 250 to 15,000 cu.ft. per hr. It passes combusted gases through a ceramic packed absorber tower through which the scrubbing liquid trickles. The CO_2-free gas leaves at the top and passes through a vapor trap or water cooled condenser. This gas may then be dried as desired. The used absorbent passes to a stripping tower and boiler where it is regenerated as above described; heat exchange between the used and fresh absorbent conserves heat.

The absorbent used in this separate unit, just described, is also a 10 to 20% aqueous solution of mono-ethanolamine. It will handle up to 20% CO_2 in the inlet gas and is said to reduce CO_2 to 0.0% by Orsat analysis. With careful operation and good equipment, losses of absorbent are quite low — reported as only 10 to 20 lb. per 1,000,000 cu.ft. of gas produced. Tetramine was used in some early installations as it is somewhat more efficient in its scrubbing action, but proved to be too corrosive for satisfactory use.

Combustion chambers for these nitrogen generators are usually to be operated on the desired side of perfect combustion, so that minor variations in gas or air supply will not cause the combustion to cross to the other side of perfect neutrality. Excess scrubbing capacity is also provided to take care of minor variations. These systems require a fairly large investment and ordinarily can only be justified where there is a large and constant demand for an atmosphere of this type. With a substantially pure nitrogen atmosphere base, corrective amounts of CO or of H_2 may be readily used to give sufficiently reducing conditions to counteract the small amounts of oxygen that may be present in the furnace.

Mention should also be made of inert gas generators for producing gas for uses other than the protection of hot metals. Examples are found in the paint and varnish industry and in food processing. The preparation unit is essentially the same as described but the combusted gas is only dried before use and contains N_2 and CO_2. No CO_2 scrubber is required for many of these units. A typical analysis for such an atmosphere is reported by C. M. Kemp Mfg. Co. as: 12.5% CO_2, with no O_2 in the presence of up to 0.5% CO, or no CO in the presence of up to 0.5% O_2; balance substantially N_2.

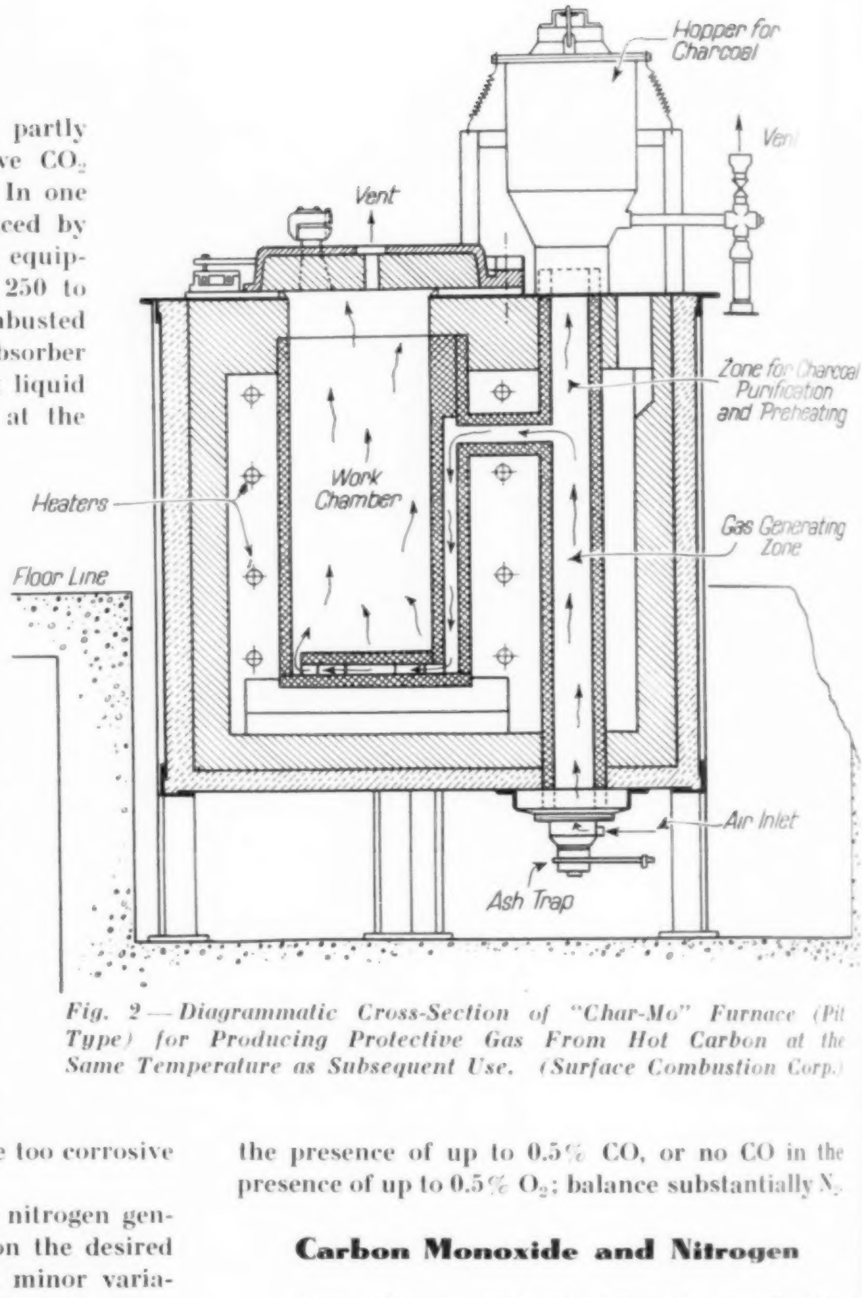


Fig. 2 — Diagrammatic Cross-Section of "Char-Mo" Furnace (Pit Type) for Producing Protective Gas From Hot Carbon at the Same Temperature as Subsequent Use. (Surface Combustion Corp.)

Carbon Monoxide and Nitrogen

Atmospheres produced from the combustion of carbon were early suggested. Difficulties in handling solid fuel and in obtaining sources of carbon free from objectionable impurities, however, had prevented any wide use of such atmospheres. One solution of these problems has recently been made in the "Char-Mo" generator by Surface Combustion Corp. (Fig. 2). When air and carbon are used to feed this device the resultant atmosphere consists essentially of carbon monoxide and nitrogen. (Small amounts of hydrogen or carbon dioxide may be present, but oxygen and practically all of the water vapor are eliminated.) This generator produces the desired atmosphere by passing the air, or other gas, over carbon which is at the same temperature as the steel being treated; its basic principle is that an atmosphere in equilibrium with carbon at a given temperature will be non-decarburizing (and non-oxidizing) to any steel *at the same temperature.* The most important operating feature of the device is that the carbon used (which may be charcoal, coke or

other equivalent carbonaceous material) is preheated in the apparatus before actual use as a source of atmosphere gases, and deleterious elements in it are driven off during this pre-heating and never come into contact with the steel being heat treated.

As shown in Fig. 2, a generator of this type consists primarily of a vertical retort which is ordinarily mounted in the heating space of a full muffle furnace. (The retort can, of course, be mounted in its own furnace for certain uses.) This retort is made of a high temperature refractory such as silicon carbide, or of a heat resistant metallic alloy, depending upon the temperature of operation. A hopper having sufficient capacity for about 24 hr. operation is mounted directly over the retort and feeds by gravity. This hopper is relatively gas tight but has a vent or burner through which 5 to 10% of the produced gas is bled off to purge out any gases evolved on preheating the carbon. The retort itself is provided with a take-off within the furnace whereby the atmosphere produced by the combustion of purified carbon is conducted into the muffle. At the bottom of the retort is a means for removing ashes and introducing air, or other gas, for the atmosphere production.

Hopper and retort are filled with carbon before the equipment is started. With the furnace and retort at the desired temperature air is introduced in such amounts that the proper flow of the prepared atmosphere passes to the muffle. A small amount is by-passed up the retort, through the hopper and out the vent burner, effectively removing water and volatile impurities from the carbon before it reaches the gas generating zone. The effectiveness of this by-passing treatment may be seen in analyses on the muffle gas and the vent gas. Vent gas analyses do not show water, but tests on samples of the muffle gas have shown dew points as low as −25° F.

Effect of By-Passing Treatment

Component	Retort at 1550° F.		Retort at 2200° F.	
	Vent Gas	Muffle Gas	Vent Gas	Muffle Gas
CO_2	3.6	0.7	3.8	0.1
O_2	0.0	0.0	0.0	0.0
CO	28.7	33.1	30.6	34.5
H_2	7.4	2.1	7.7	1.2
CH_4	0.0	0.0	0.0	0.0
N_2	Balance	Balance	Balance	Balance

The actual composition of the atmosphere produced by this type of generator is a function of the temperature of operation. The hydrogen content depends upon the humidity of the air, since any moisture in the inlet gas is converted into H_2 and oxides of carbon within the retort. (Hydrogen could be eliminated by drying the inlet air but for practically all uses a small amount is not detrimental.) Since the muffle gas is withdrawn from the retort at a point where the temperature is approximately that of the work, there is no decomposition of CO into C and CO_2 at temperatures lower than the temperature of formation.

Since this atmosphere depends for its effective operation upon the fact that an atmosphere in equilibrium with carbon will also be at equilibrium with a steel (that is, neither decarburizing nor oxidizing) it is obvious that the apparatus must be so constructed and operated that a fairly close approximation of equilibrium is obtained. If anything should allow air to get into the muffle, sufficient CO_2 to decarburize or even oxidize the work may be produced; however, since the muffle is operated under slight pressure there is little chance for air infiltration.

Advantages are said to be: Infiltration of air does not produce appreciable water vapor since the atmosphere is low in hydrogen; a hydrogen-free atmosphere may be made if desirable; the gas composition is simple and many intergas reactions are thereby eliminated; for a given temperature the atmosphere produced is relatively constant regardless of outside conditions; true non-decarburizing hardening can be accomplished; the cost is relatively low, being about 30 to 50¢ per 1000 cu.ft. on the basis of the cost of the charcoal. While air is the usual gas passed up through the retort, others such as dried flue gas, dried ammonia combustion products, partly burned gas, and special producer gas may be used for special atmospheres.

Another solution to the problem of generating satisfactory atmospheres from carbon is to use very pure carbon as the source. One apparatus manufactured by Lindberg Engineering Co. for this purpose combines a generator of this type and a heat treating furnace into a compact unit (Fig. 3). The heat treating furnace may be of any type, but this one is an electric box type with a hinged hearth to permit quenching while the work is still protected by the controlled atmosphere; hardening without decarburizing or any oxide forming on the surface is said to be obtainable. Tubular electric heating elements may be used to reduce the temperature differential between elements, furnace and work.

The generator consists of an insulated refractory tube, charged with carbon from a storage space above the hot zone. The opening is sealed during operation and recharging is done by hand about once a shift. The fuel bed is supported upon a perforated steel grate and ashes are shaken down

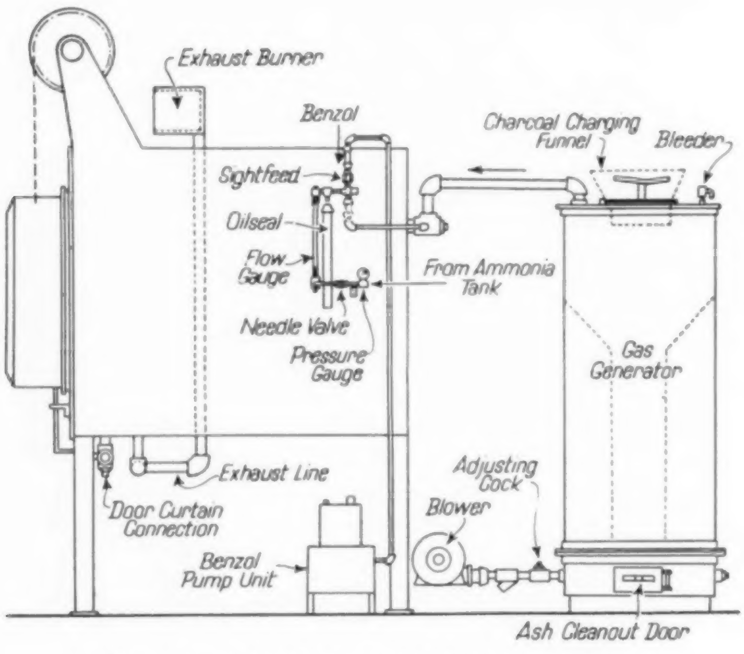


Fig. 3 — Lindberg Engineering Co.'s "Hydryzing" Unit, Using Charcoal Producer Gas Enriched With Benzol, Ammonia or Both

occasionally by a hand lever. Air is passed into the bottom and passes up through the combustion zone where it forms an atmosphere of CO, CO_2 and H_2 which is passed to the heat treating furnace. Since this usually results in more CO_2 than is found if static equilibrium were reached in the exit gas, some means must be used to combat the decarburizing effect of this excess CO_2 on high carbon steels. This is done by dripping a little benzol into the producer gas to increase its content of carburizing elements. To increase the reducing power of the mixture, anhydrous NH_3 may be introduced into the heat treating furnace where it decomposes to N_2 and H_2.

No adjustment of this atmosphere is said to be required for heat treating most toolsteels under the usual time-temperature conditions. Widely different types of steels or unusual heat treating conditions require some variations in the benzol and ammonia additions. For example, with very low carbon steels the benzol may be eliminated, while with steels which are particularly susceptible to decarburization the benzol may be increased over the usual amount.

Carbon used in this generator must be pure. Double-retorted pellet charcoal, about ¼ to ½ in. in size, is ordinarily used. As in other generators of this type the specified rate of atmosphere production for a given unit must not be exceeded or abnormally high CO_2 or even O_2 will be found in the product gas. A small amount of fly ash carries over, but it has been found more practical to blow out the furnace at intervals than to try to separate it in dust-collectors.

Dry methods of removing CO_2 from partly burned atmospheres also offer promise in forming mixed atmospheres of CO and N_2. The General Electric Co. has developed an apparatus for producing an atmosphere of this type (termed "dry-colene" since the atmosphere consists essentially of dry CO and nitrogen). Because of its freedom from decarburizing gases, it is recommended by the makers for scale-free hardening, and bright annealing or brazing of high carbon steels without decarburization.

In producing this atmosphere, gas and air are burned slightly on the reducing side of complete combustion. The products are cooled to remove the water produced by combustion, and the remaining gases are passed over incandescent carbon to convert the CO_2 to CO. The final atmosphere is chiefly CO and N_2 with small amounts of H_2 and may have a dew point as low as $-50°$ F.

By supplementary use of an electrically heated retort containing the incandescent carbon, any partly burned gas may be converted into an atmosphere of this type. If gas is used to heat the carbon, self-contained units are available. The latter will be described in some detail since it embodies all of the salient features. The flow diagram is given in Fig. 4.

Fuel gas and air are metered and mixed according to conventional practice. The gas mixture is burned around an alloy retort which contains the carbon (charcoal) used in the subsequent conversion process. An example of the composition of the flue gas formed at this stage is 9% CO_2, 0.5% CO, no O_2, 10 to 20% H_2O and balance N_2.

This gas passes to an externally mounted surface cooler where the bulk of the water is removed, down to 1 or 2%. If it is desired to reduce hydrogen in the finished atmosphere to a minimum, all of the moisture must be taken out and an activated alumina drier must follow the surface cooler. Usually, however, this is unnecessary and the gas passes to the hot carbon, held at 1850 to 2000° F. by regulating the amount of raw gas burned to heat it, at the same time keeping the amount of CO_2 conversion constant. This is accomplished by bleeding off some of the gas between surface cooler and charcoal retort.

In contact with hot carbon the CO_2 is converted almost completely to CO (and H_2O, if present, is converted to H_2 and CO). The resultant gas passes through a filter to remove charcoal dust and is then ready to use in heat treating applications. While some range in composition may be had, a typical analysis is 20% CO, no O_2 or CO_2, 2% H_2 and balance N_2. The gas is quite dry, the dew point being about $-30°$ F.

Carbon is fed by gravity into the producer from a hopper at its upper end. The unit holds sufficient carbon for a day's operation plus a reserve. Recharging may be accomplished by manual reloading of the hopper when its cover is

removed, or by a vacuum charging method. Charcoal consumption depends upon the rate of flow of the gas and its CO_2 and H_2O contents, but the average figure is about 3 lb. per hr. in the standard unit producing 750 cu.ft. of gas. No. 3 size hardwood high-charred charcoal is suitable; it costs around 2¢ per lb. This makes the charcoal cost for the standard unit about 6¢ per hr. or 8¢ per 1000 cu.ft. of atmosphere produced.

Atmospheres of Carbon Monoxide, Hydrogen, and Nitrogen

While $CO\text{-}H_2\text{-}N_2$ atmospheres are relatively old, their production from the partial combustion of air and natural gas with only small amounts of methane in the product gas now appears to be of sufficient importance to justify a description. This gas is prepared by the thermal reaction whose ideal form is

$$2\,CH_4 + O_2 \longrightarrow 4\,H_2 + 2\,CO$$

A typical gas produced by a generator of this type manufactured by Westinghouse Electric & Mfg. Co. using 42 parts of natural gas to 100 parts of air is 20.5% CO, 40.5% H_2, 1.2% CH_4, 0.5% CO_2, no O_2, 0.15% H_2O (dew point, approximately −15° C.) and balance N_2. Such gases are particularly applicable to short cycle annealing at 1350 to 1650° F., where it is desired to avoid decarburization (or to carburize slightly). Successful applications have been reported at temperatures above 1750° F., where time of treatment has been short.

An atmosphere of this type is prepared by passing a gas-air mixture over a heated catalyst. Since it is necessary to oxidize the hydrocarbon gas practically completely yet avoid the production of CO_2, the cracking reaction requires careful control, uniform heat, and proper design of the cracking chamber. Nickel is the common catalyst, and is prepared in any of the usual ways for depositing nickel upon a refractory. The retort is also made of nickel. Carbon precipitation must be avoided; sooting at the cool end of the retort was very troublesome until the nickel tube at this point was replaced by a metal which did not promote the reaction. Good heat transfer is secured by winding a metallic resistor in the catalyst itself. This resistor is operated at about 1800° F., its usual maximum operating temperature.

The atmosphere is said to be satisfactory for hardening of most steels without decarburization; the apparatus can be easily controlled, and no drying of the product gas is required.

Gas Engine Exhaust

Many gases produced by the partial combustion of fuels have been used for "controlled furnace atmospheres", but it is only recently that gas engine exhausts have been used on a commercial scale. A device called the "Petrolair Gas Preparation Unit" made by Hevi Duty Electric Co. is shown in Fig. 5. This unit consists of a gasoline engine, a condenser for cooling the exhaust gases, and a receiver for additional water condensation and smoothing out the exhaust gas pulsations. The engine of the unit may be loaded with a blower or other machinery requiring a steady flow of power.

The engine may operate on straight gasoline without antiknock constituents, any of the liquefied hydrocarbon gases, natural gas or manufactured gas. The composition of the exhaust depends upon the fuel and the carburetor setting, and varies in about the same manner as gases produced by

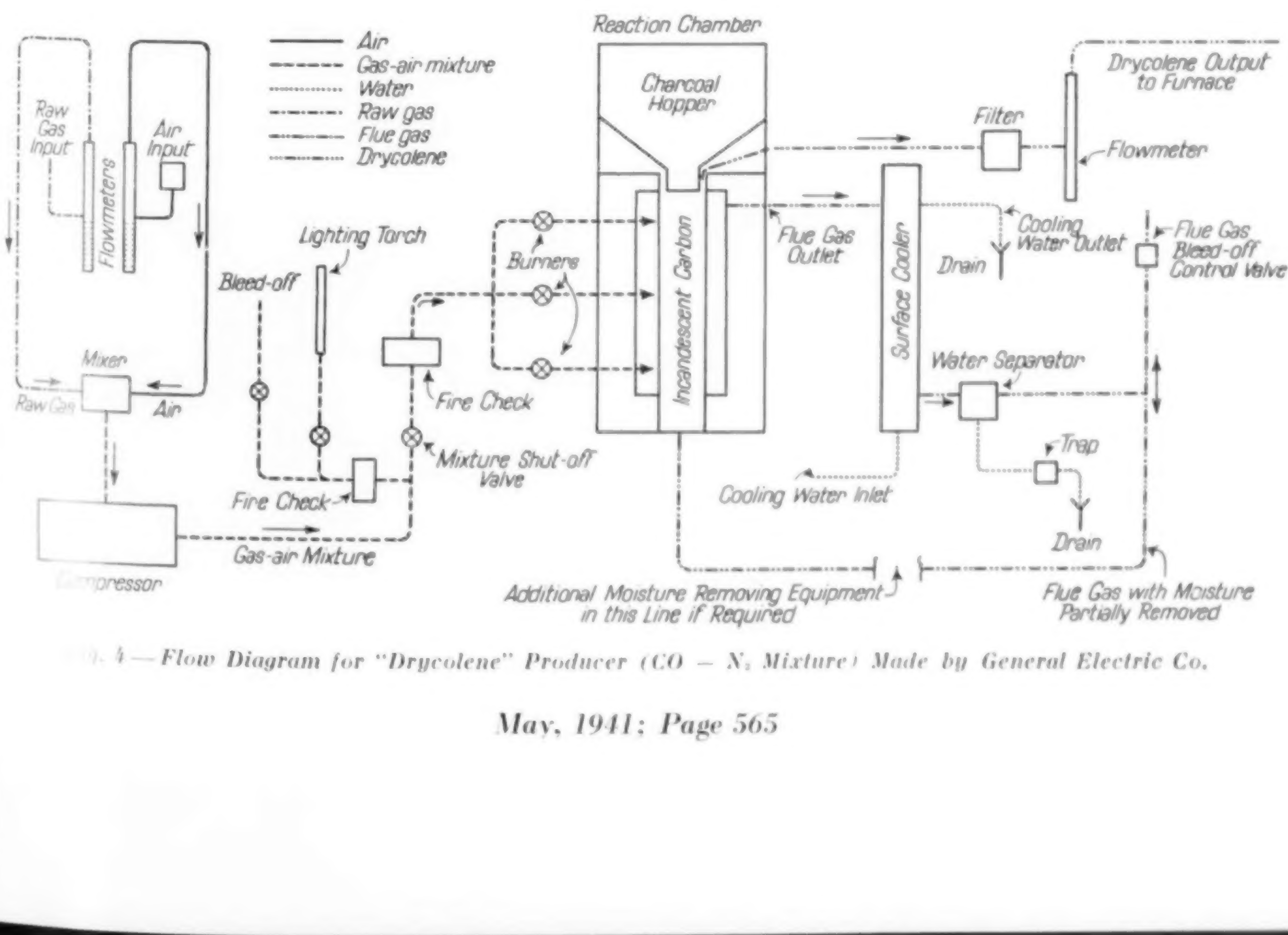


Fig. 4—*Flow Diagram for "Drycolene" Producer (CO — N_2 Mixture) Made by General Electric Co.*

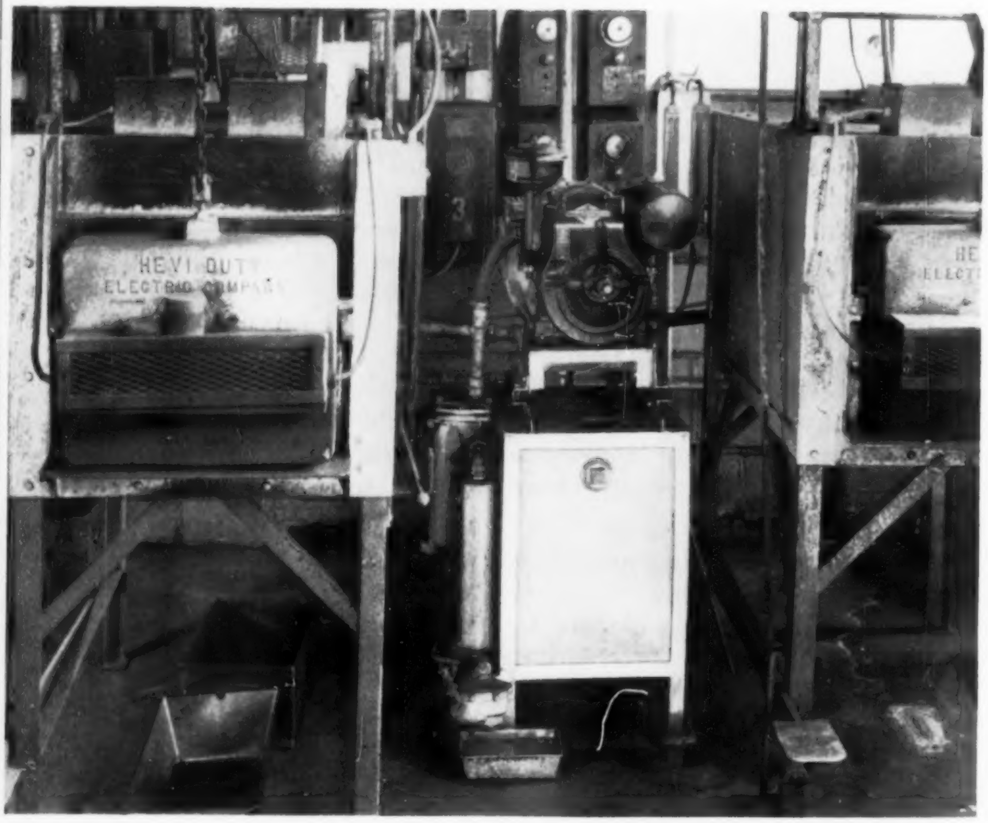


Fig. 5 — "Petrolair" Preparation Unit Serving Two Small Furnaces With Exhaust of Small Gas Engine. Hevi Duty Electric Co.

the partial combustion of the same fuel in a combustion chamber. However, it is claimed that the high explosion temperature of combustion produces a more stable atmosphere than the one from ordinary flame combustion. The carburetor is usually set for a rich mixture so as to produce an atmosphere high in reducing gases.

As soon as the engine is started the gases are available for use. The exhaust is led to a water condenser to separate the bulk of the moisture and then to a receiver tank which is of comparatively large volume and serves to dampen the pulsations produced by the engine exhaust. Gas from this tank is usually passed directly to the furnace, though sometimes it goes through other equipment such as a chemical drier to remove more water vapor, or a device to add other constituents to the gas.

The utilization of the power developed by the engine depends upon the characteristics of the particular installation. Where air is required for furnace combustion, a blower is frequently used to absorb the power and, in at least one case, a portion of the power is used for the compression and refrigeration of the exhaust gases prior to use. It is desirable that the engine be fairly well loaded so as to make the unit more efficient and to provide a means for speed control. The engines in small units are the air-cooled variety; their hourly output varies from 150 to 750 cu.ft. of prepared gas.

Flame Annealing

One of the most recent applications of controlled atmospheres has been in the open-flame annealing of non-ferrous wire, developed by Syncro Machine Co. and Surface Combustion Corp. In principle it is extremely simple, the wire being passed through a flame at a point where the products of combustion are non-oxidizing to the work and at such a rate that the wire is suitably annealed or softened. To put this process into plant operation, however, requires refined control. The apparatus consists of a long series of slot type gas burners, supplied with a constant gas-air mixture, gas of constant heat value, and at constant pressure. The burners themselves are accurately made, being held to a 0.006-in. tolerance in width. Air and gas are mixed in about the theoretical ratio for complete combustion. This produces a short flame about 4½ in. long, as wide as the slot and extending for the length of the apparatus. Positioning dies hold the wire being annealed at intervals in the proper portion of the flame. Careful control of the wire speed is required to prevent overheating or under-annealing; up to 1500 ft. per min. has been attained when heat treating the smallest sizes of wire.

Numerous novel mechanical devices are used, but the important fact from the controlled atmosphere viewpoint is that bright annealing is secured without the use of a furnace or any other enclosed space. As a consequence, no heat is lost to the furnace. Straight-line production is facilitated, long-cycle heating is eliminated and the operation can be rapidly and efficiently started and stopped. As yet this process is limited to certain sizes of wire; while it appears valuable for wire, it has obvious limitations which prevent its use for much heat treatment.

Conclusions

The recent trend in the development of new equipment for the production of controlled atmospheres has been directed to the making of atmospheres which are as nearly as possible in equilibrium with the material to be protected. For high temperature heating of medium and high carbon steels, this has usually meant the elimination of CO_2 as well as H_2O, either by avoiding their production or by removing them after formation. Removal after forming may be by wet methods — that is, scrubbing the gas through mono-ethanolamine or other CO_2 absorbent — or by dry means as passing over hot carbon. *(Continued on p. 628)*

CHROMIUM STEEL FOR BALL BEARINGS: INSPECTION AND HEAT TREATMENT

By Alfred S. Jameson
Metallurgist, International Harvester Co.
West Pullman Works, Chicago

ESSENTIAL REQUIREMENT of materials for ball and roller bearings is that they should be capable of being heat treated to resist wear, plastic deformation and fatigue.

Bearing parts are subjected to rubbing wear due to inaccuracy in dimensions and adjustment, to chemical wear because of their contact with the atmosphere or lubricants containing impurities. They must have a high elastic limit so that under load they will not plastically deform, a high fatigue resistance as they are under alternate compressive and tensional stress of a high order.

In choosing a suitable material economic factors must also be considered, which means that the cost of material must be as low as is compatible with the physical requirements.

Confining attention now to ball bearings of moderate size (under 6 in. diameter) it should first be noted that the component parts are inner race, outer race, balls, retainers, and studs. Compositions of steels ordinarily used for these parts are shown in the table opposite.

No further attention will be given to the retainer and stud material except to state that this steel is made in openhearth furnaces and is cold rolled to strip. The retainer material is annealed in process to a soft temper (about Rockwell B-55) for deep drawing, and the stud material rolled to B-90.

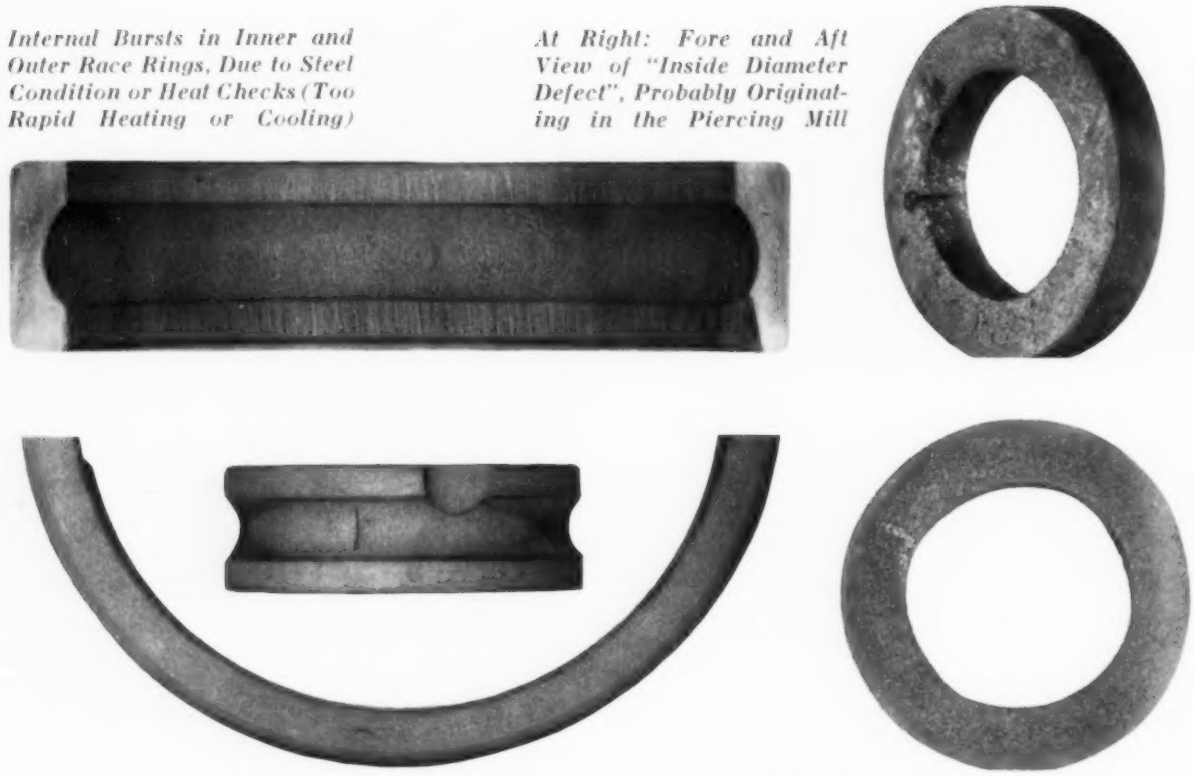
It will be noted that as the ball size increases the chromium content is increased to insure complete penetration of hardness from surface to center.

Steel for race rings and balls is made in electric furnaces of capacities from 6 to 25 tons, cast in molds of suitable size and rolled under controlled conditions to bars for forging or tubes for machining.

Approaching the material from a consumer's standpoint, certain metallurgical requirements are agreed upon with the steel maker and these are subject to inspection control. Let us follow this, in the case of the race ring steel, and note the reasons for these requirements.

Chemically, there is a specified minimum and maximum range of elements. Carbon control on this type of steel is based on a 15-point range and the manganese on a 30-point range. Sulphur and phosphorus are usually held to a combined maximum of 0.05%, the silicon to a 15-point range and the chromium to a 30-point

Element	Race Rings	Balls		Retainer and Studs
		1/8 to 15/32	1/2 to 13/16	
Carbon	1.00	1.00	1.00	0.15
Manganese	0.35	0.35	0.35	0.40
Sulphur	0.015	0.015	0.015	0.025
Phosphorus	0.015	0.015	0.015	0.025
Silicon	0.25	0.25	0.25	0.05
Chromium	1.40	0.50	0.95	nil



Internal Bursts in Inner and Outer Race Rings, Due to Steel Condition or Heat Checks (Too Rapid Heating or Cooling)

At Right: Fore and Aft View of "Inside Diameter Defect", Probably Originating in the Piercing Mill

Fig. 1 — Defects in Bearing Races, Rough and Finished, Revealed by the Deep Etch Test. Full size

range. The method of sampling and analyzing for these elements is well standardized and will not be commented on.

Due to the change in volume (shrinkage) when liquid steel solidifies, a cavity known as a "pipe" is formed in the top part of the ingot. It is localized as to depth by proper design of ingot mold, shape of ingot and use of hot top to keep the upper portion liquid to the last. However all metal above the bottom of the cavity must be discarded, else the resulting bar after rolling will have a central defect, and this is usually done by cropping the bloom (the product of the first rolling operation).

All operations in the casting, stripping and reheating of fine steel ingots must be carefully done, else dangerous defects will be caused either on the surface or deep seated. Likewise rolling mills cannot cure many of these — in fact they may be responsible for some. Surface defects can often be cut out of the blooms; internal bursts due to improper heating or rolling practice ruin the steel. Should the steel be rolled at too low a temperature definite discontinuities may be mechanically produced. It is possible also that under certain conditions in the melting practice, gas may be in solution and be liberated in the casting, remain entrapped and form a discontinuity in the metal.

These types of internal defects are disclosed by the deep etch test, wherein a section of a bar, tube or billet after etching in 20% sulphuric acid or a 50% solution of hydrochloric acid is examined. Central porosity or sponginess, if present, is clearly evident after this pickling; likewise bursts, blowholes, large segregated areas or slag particles are readily exposed. Good sound steel roughens, in pickling, to a rather uniform matte surface.

Skill and experience are necessary to interpret these macrostructures (so-called) else good and useful steel be rejected for some slight deviation from pattern that has no discoverable practical significance — or, on the other hand, unsuitable steel accepted and put into production with eventual loss and disappointment. Doubtful cases should be segregated, and parts made therefrom studied in various stages of production to see whether the suspicions are confirmed or are groundless. Figure 1 shows some defects in bearing rings, both rough and finished, revealed by the deep etch test.

It is natural to expect that there will be some decarburization of the surface during the various heating and rolling operations, due to the oxidizing influence of the air and scale which comes in contact with the surface at a relatively high temperature. This "bark" or decarburized zone must be removed from the surface before hardening. Machining allowances both on forgings and bars and tubes for machining must take this into account. Should the bark be

thicker than expected the race rings will have soft surfaces after heat treatment. It is necessary, then, to set limits on depth of decarburization; it will vary with the size of material but a fair limit for rolled products would be about 0.025 in. Figure 2 shows a section normal to the surface of a 1.40% chromium steel bar, etched to bring out the normal structure below and leave the almost pure iron at the surface uncolored.

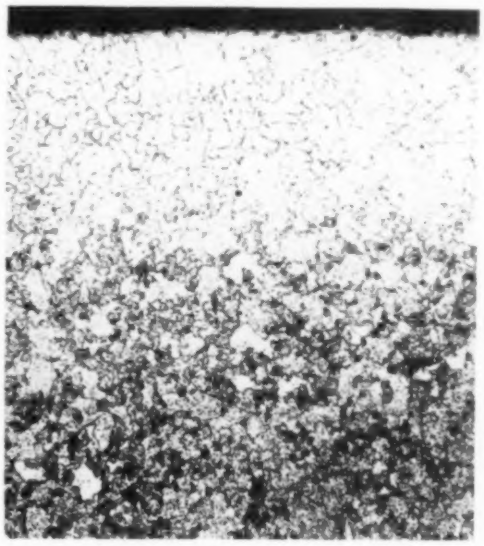


Fig. 2 — "Bark" on Bearing Race Steel. Etched with nital; magnified 100 diameters. Practically completely decarburized to a depth of 0.010 in.; carbon is lost as deep down as 0.020 in.

In ball bearing material it is considered advisable to hold the non-metallic inclusions in the steel to the minimum. Their presence (or relative absence) is a function of the steel making practice. It seems impossible to eliminate them entirely, even when fine steel is made under the best known melting practice.

Opinion as to their effect, within the limits of the amounts usually present, on the life of a bearing part is not unanimous. It is safe to say that when their location is within the stressed area of the part, they act as "stress raisers" and become focal points for the commencement of fatigue failure. The most popular method of estimating the extent of their occurrence is by polishing a longitudinal section taken from a given location in the steel shape and examining it microscopically without previous etching at a magnification of 100 diameters.

As for methods used to record the amount of inclusions: One method is to compare the field under observation with a prepared chart in which different photomicrographs representing amounts and also types of inclusions are assigned numbers and letters. One such chart widely used in the automotive industry is given on page 378 of the October 1940 Reference Issue of METAL PROGRESS. Another method is to measure the length and width of the inclusion by a micrometer eye-piece and record the areas. Where the inclusions are of the same general character (as they are in most ball bearing steels) this usually results in a classification by length, as their width is negligible.

We will now deal with another important consideration and that is grain size of ball bearing steel. Austenitic grain size in terms of a McQuaid-Ehn test, or a grain size determined at 1700° F. is not usually called for. The grain size is considered in relation to the hardening range of the material and therefore fracture tests are made after quenching within a temperature range of from 1450 to 1600° F., usually by heat treating specimens (disks from bars or tubes, or round specimens of a section comparable with the parts to be hardened) fracturing them and rating them numerically with a standard set of specimens. Shepherd fracture standards are useful, or a graded set of duplicate fractures of own preparation may be used by purchaser and vendor.

Of late there has been a tendency to include hardenability tests made on standard size specimens as part of the material requirements. In the present state of the steel industry the making of steel within the chemical ranges of any one grade to a hardenability requirement is very difficult, and is not generally acceptable by the industry. Control of the hardenability is a part of the melting practice. It will be dependent on the raw materials used, the melting temperature, the time within the refining cycle, on ore additions (if any), deoxidizing additions,

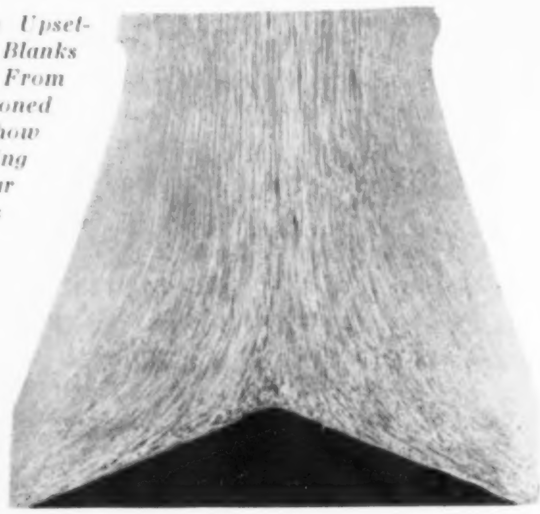
Fig. 3 — Average Hardenability (by the Jominy End Quench Test) of 28 Heats of Ball Bearing Race Steel

and perhaps other factors. However, from a user's standpoint, there is no question that standard hardenability tests are useful in determining the application for given parts of different analysis grades. This matter has been recently discussed in this magazine by WALTER JOMINY, the originator of a commonly used hardenability test.

Values in Fig. 3 (page 569) were obtained from 1-in. round specimens, 3 in. long, end quenched by JOMINY's method. Quenching medium was water at 70 to 80° F.; the bars had previously been spheroidized by annealing, and were quenched from 1550° F. Variation in chemical analysis of 28 heats of steel so tested is noted on the diagram.

This concludes a review of the properties which are a part of steel making technique.

Forged ball bearing race rings are usually made by upsetting from hot-rolled bars by steps shown in Fig. 4. In these views the bar (and the resulting ring) have been sectioned down the diameter, smoothed, and deep etched to show the "fiber" or forging flow lines. The action is very simple. An expanding tool spreads the metal from the center outward into an annular shoulder in the die of correct diameter, and then this shoulder is sheared off to form a complete ring. The operations are so planned that the flow lines are parallel to the axis of the ring.



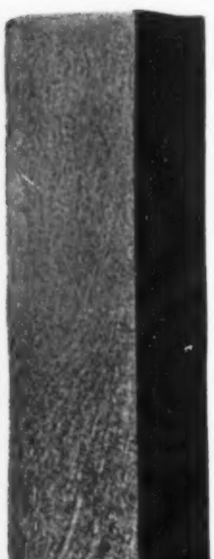


Fig. 4 — Steps in Upsetting (Forging) Blanks for Bearing Races From Round Bar; Sectioned and Etched to Show Flow Lines. Ring cut from upset bar enlarged 3 times

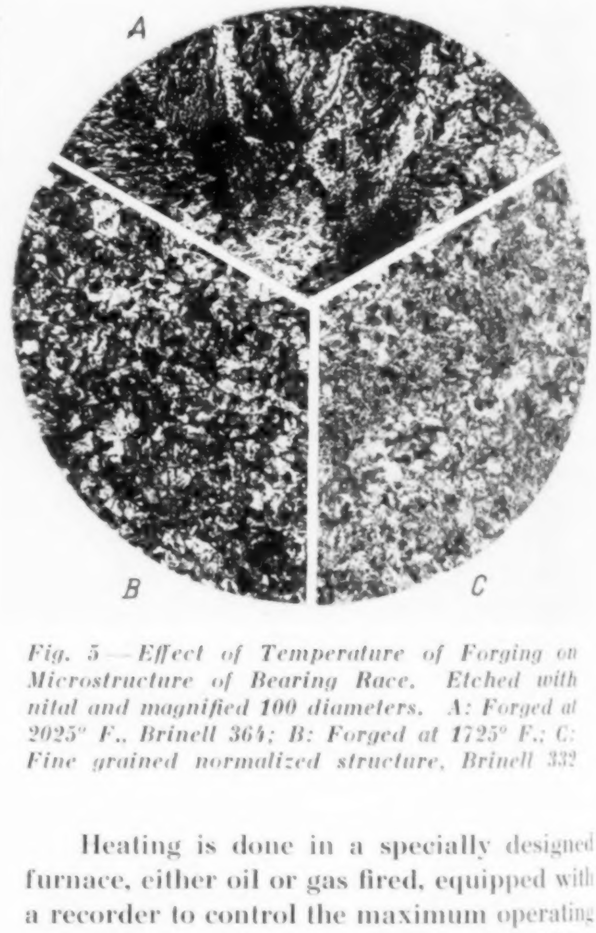
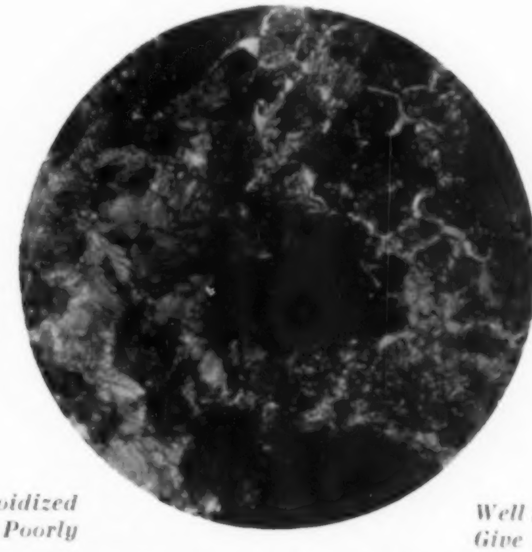


Fig. 5 — Effect of Temperature of Forging on Microstructure of Bearing Race. Etched with nital and magnified 100 diameters. A: Forged at 2025° F., Brinell 364; B: Forged at 1725° F.; C: Fine grained normalized structure, Brinell 332

Heating is done in a specially designed furnace, either oil or gas fired, equipped with a recorder to control the maximum operating temperature. The temperature of the bars themselves is controlled by the time they are in the furnace; as the temperature of the furnace is higher than that desired for the work, the heating *time* is quite important. A temperature of 1980° F. is the most common forging temperature. As a number of rings are forged from each bar there will be a temperature drop of about 180° F. from the first to the last ring. The furnace will usually be controlled at about 2250° F.

The micro-grain size of the forged steel will naturally vary with the forging temperature. Longer time at higher temperature in the furnace will permit the austenitic grains to grow — that is, some favorably placed grains swallow up their

Fig. 6

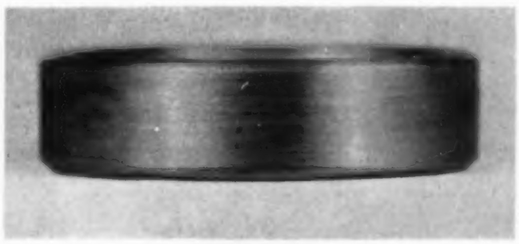


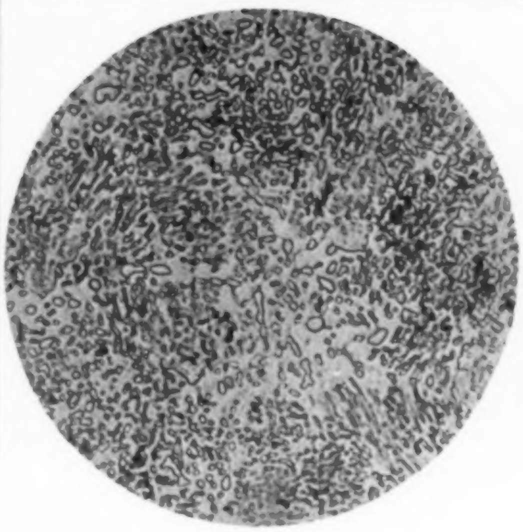
Normalized Chromium Bearing Steels. (All micros at 1000 diameters, etched with nital)

Profilograph of Rough Surface

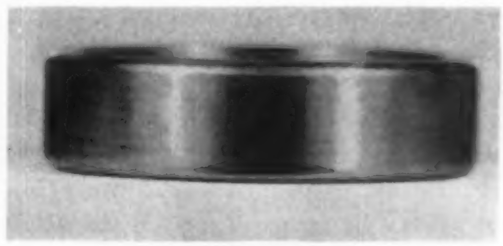
Profilograph of a Good Surface

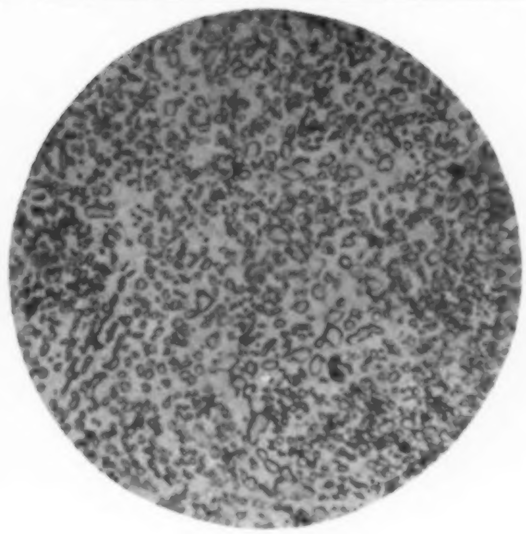
Below: Poorly Spheroidized Structure Machines Poorly





Well Spheroidized Carbides Give Much Better Surfaces





unfavorably placed smaller neighbors and the average size becomes larger. The forging operation kneads these grains around and probably breaks them up, but grain growth at the expense of the small fragments starts (and continues possibly even more rapidly) as soon as the working stops. Rings made from a hot bar then would have a coarser grain size when cold than rings made from a cooler bar, because the former is a longer time above the temperature of grain growth. These facts are shown in the micros of Fig. 5.

It is good practice to normalize forgings before annealing for machining. Figure 5-C illustrates the change in micro-grain size from the forged to the normalized structure. The normalizing treatment will also re-form the carbide envelopes around the austenitic grain boundaries into smaller, more spherical forms. Annealing is carried out for the purpose of softening the steel for machining and preparing the carbides for hardening. A typical normalizing heat treatment for the 4-in. ring shown in Fig. 4 is as follows: Heat to 1650° F., hold 4 hr., and cool in air.

Figure 5 is at such low magnification that the real structure of the normalized sample is not evident. Consult Fig. 6, at 1000 diameters, and it is seen to be a more-or-less interrupted network of cementite (white) surrounding pearlite grains, some of the pearlite being so fine that it disappears into black, heavily etched or unresolved areas. Such a structure is a desirable intermediate stage to the fully spheroidized, machinable structure also shown in Fig. 6.

The spheroidized structure consists of two constituents, carbide particles and ferrite. The hardness is reduced by this treatment from

Rockwell C-35 or 332 Brinell to Rockwell B-87 or 170 Brinell. A typical annealing cycle is to heat to 1500° F., hold for 8 hr.; cool to 1300° F. in 20 hr. and cool to 1100° F. in 10 hr. — that is, cool from the soaking temperature at the slow rate of 10° F. per hr. to 1300° F. and 20° F. per hr. to 1100° F.

Mill Annealed Bars and Tubes

So much for the preparation of forged parts. Bars and tubes are also much used and ball bearing parts cut from them on automatic screw machines. These are received by the user in the spheroidized annealed condition, and certain restrictions are made on the shape and size of the carbide particles and the hardness (which includes microstructural conditions that control hardness). See Fig. 6 for an illustration of acceptable and unacceptable carbide form and distribution.

In the insufficiently annealed structure there remains much pearlite, and the envelope carbides are not entirely broken up. Another unacceptable structure looks like the acceptable, except that there are relatively few small particles; the largest carbide particles are two or three times the area of the largest in the good structure.

The reason for the restriction in the size of the carbides is the relative insolubility (or slow solubility) of the larger particles. The hardness is usually specified in a range of Rockwell B-85 to 92 or a Brinell range of 166 to 195. An excellent example of the effect of the presence of pearlite in the microstructure on machinability and surface is also shown in Fig. 6.

During our discussion of the steel factors which are a function of the melting and casting practice, we delayed mentioning until this point a condition which also arises there — namely, carbide banding, a type of carbide segregation which is illustrated in Fig. 7. In the bars as received, the light and dark streaks are even more contrasted than after a heating for quenching; examination at high power shows that each light streak is a "Milky Way", a great accumulation of relatively large carbide particles (which do not etch and darken when the micro specimen is prepared), and the darker streaks have a fairly uniform distribution of very small particles. This condition is very persistent; the banding still exists even after forging and heat treating in several ways, as shown in Fig. 7.

What all the foregoing sums up to is the effort to condition the parts by steel selection and process control to facilitate smooth machining and hardening to a strong, wear resistant surface. Experience shows that best results in service are had when the microstructure shows uniform martensite containing undissolved carbide particles, uniformly small and uniformly well distributed. This structure will have a hardness of Rockwell C-60 to C-64.

The usual hardening range for this 1.40% Cr, 1.00% C steel in ring sections is from 1480 to 1580° F. and the quenching medium is oil. There are a number of general principles governing the behavior of this steel in hardening. An increase in the hardening temperature within

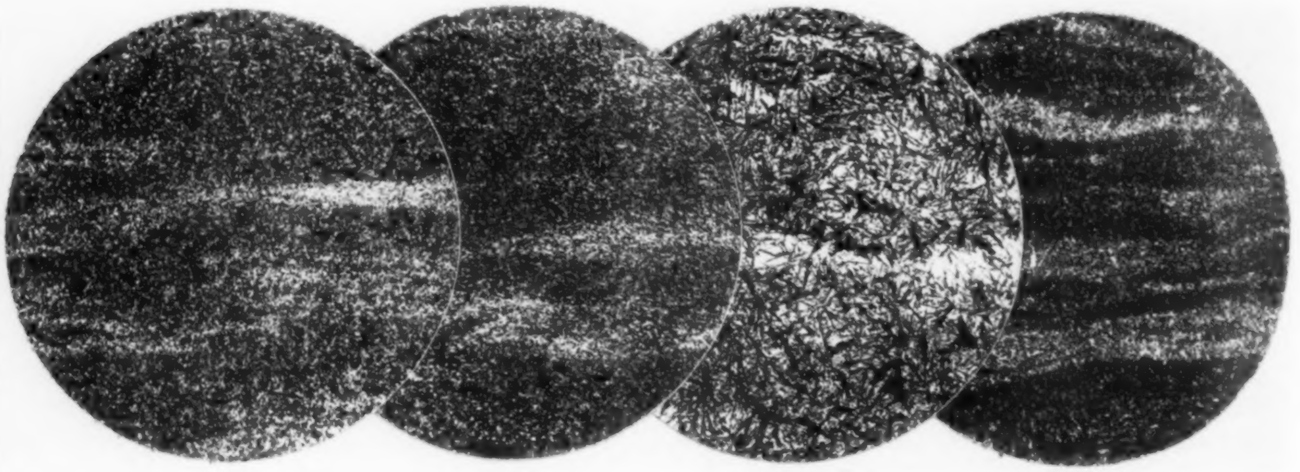


Fig. 7 — Carbide Banding Is Very Persistent in a Forged Ring of ¼-In. Wall Thickness. Nital etch; 100 ×. Left to right: 1. Water quenched from 1550° F. 2. Triple quenched in oil from 1550, 1650 and 1550° F. 3. Double oil quenched from 1550 and 1900° F. 4. Triple oil quenched from 1550, 1900 and 1550° F.

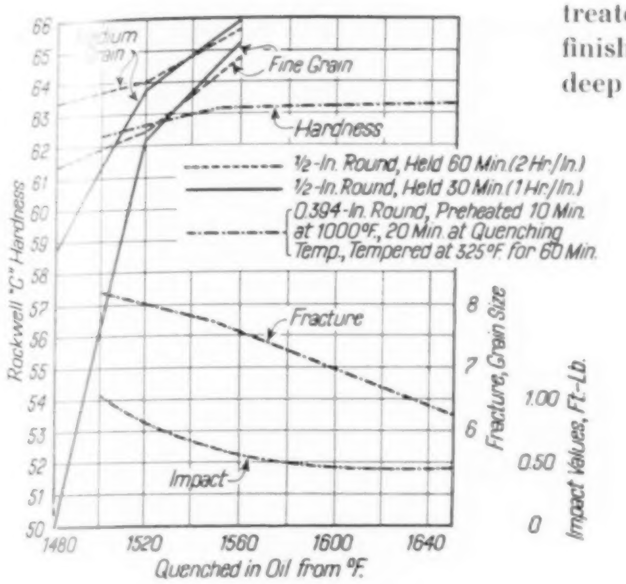


Fig. 8 — Influence of Heat Treating Conditions and Size on the Hardness, Toughness and Fracture Grain Size of Ball Bearing Parts

the proper hardening range, or an increase in the holding time at heat prior to quenching from a given temperature, results in

1. An increase in the surface hardness.
2. An increase in the hardness penetration.
3. An increase in the mass (section) that can be hardened.
4. An increase in the micro-grain size.
5. A decrease in the toughness.

Figure 8 shows these effects of the hardening temperature on the hardness, fracture grain size and impact strength, as well as the effect of the holding time on surface hardness. (Size — curvature — of balls also has an influence on the Rockwell hardness as *measured*, and this is also indicated in Fig. 10.)

Steel Balls

The metallurgy of the steel used for balls is similar to that described for the race steel, except that the requirements are if anything more rigid. The major part of the steel for balls is made under toolsteel practice, which means smaller heats and small ingots. Balls are made by a cold heading process from wire or bars up to approximately 1 in. diameter. Balls over 1 in. are usually hot forged.

After heading, balls are rough ground and heat treated to a hardness of from Rockwell C-64 to 66. The finished balls are subjected to the same tests — such as deep etch, fracture grain size, and microstructure — as rings, except that a sampling of the balls is subjected to a crushing strength test. This is carried out by compressing three balls in a vertical line until failure occurs. Assuming the same hardness and microstructure the crushing strength of a ball will increase as the diameter increases. Figure 9 shows this relationship. The crushing strength of a ball is one of the factors used for calculating load capacities of the bearings.

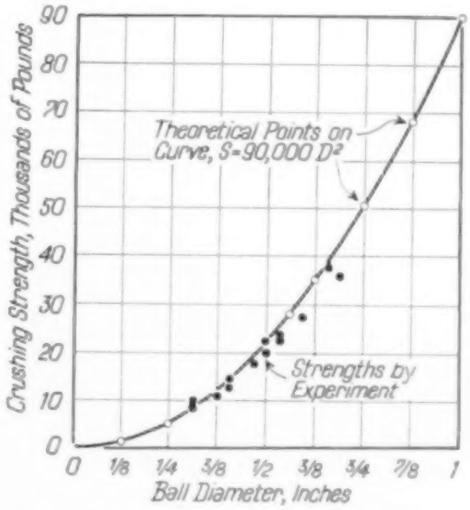


Fig. 9 — Graph Showing Crushing Strength of Balls of Various Diameters

Balls or rings after hardening are tempered to relieve internal stresses and to reduce hardness. In the case of rings the hardness is reduced from two to three points on the Rockwell C scale by tempering at 325° F. and in the case of balls the hardness is reduced about one point by tempering at 250 to 300° F. Tempering of balls may be referred to as a stress relieving operation rather than as a hardness reducing operation. The importance of a stress relieving operation on balls is illustrated by the following example: Improperly stress relieved balls, 0.812 in. diameter, had a crushing strength of 39,000 to 45,000 lb. The balls were heated at 300° F. for 30 min. and the crushing strength became 46,000 to 53,000 lb.

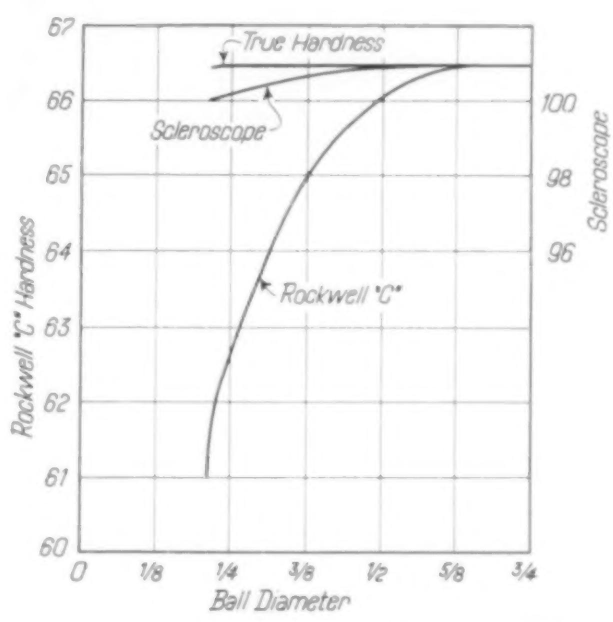
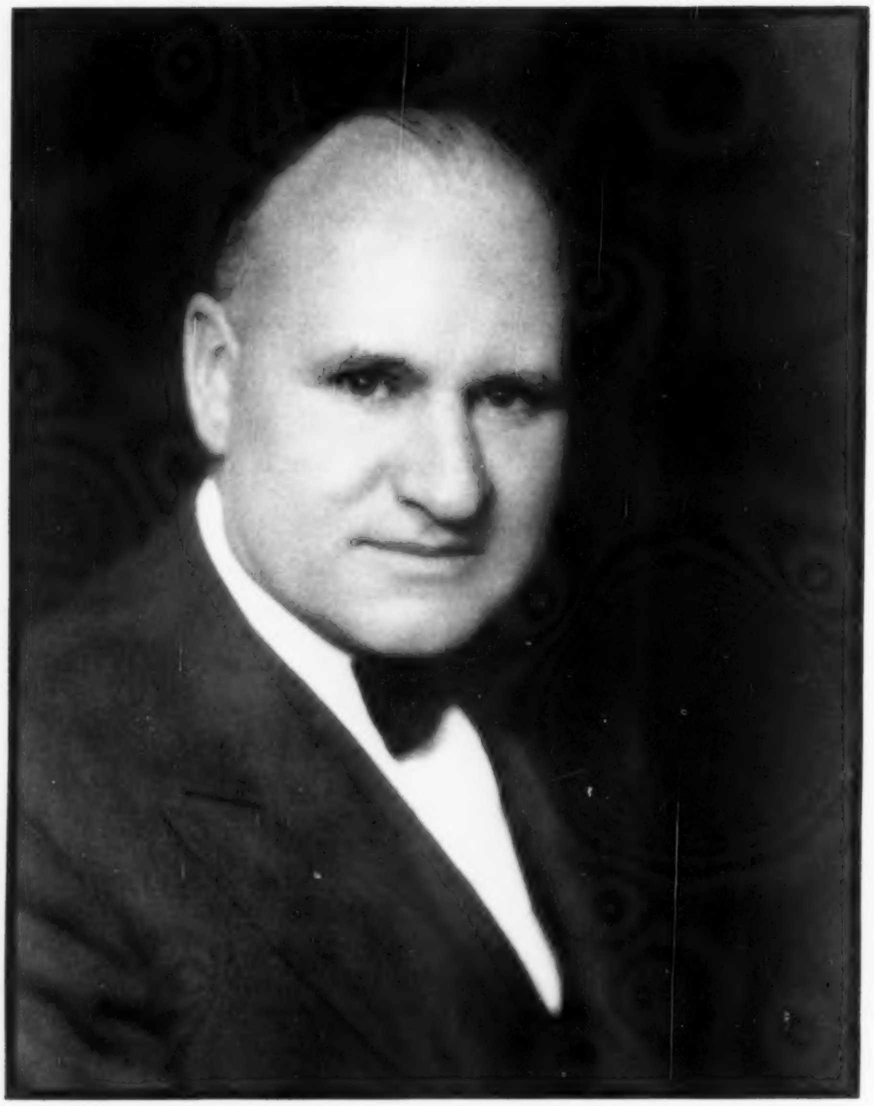


Fig. 10 — Observed Hardness Varies With Diameter

PAGES FOR A METALLURGIST'S ALBUM



Zay Jeffries

An appreciation by a former associate, Samuel L. Hoyt

METALLURGISTS are fortunate to have this man, Zay Jeffries, one of their own. Strong of body and mind, sympathetic and courteous, in complete harmony with life, and productive to a prodigious degree, his example stimulates us all to a fuller and more useful career. Thinking of him I am reminded that "A talent is formed in the quiet; character, in the storm of the world." Sound thinking and clear expression were thus fostered, and Jeffries' outstanding ability was developed for building facts and principles into broad generalizations. Another talent "formed in the quiet" was an equally great ability to appraise scientific developments for use. The significance of this harmonious union of science and technology cannot be overemphasized for it actually and figuratively took him out of the "cloister" and into the "storm of the world". Today, when met in action, he gives the impression of complete fruition of talent and character. These are the things I wish to emphasize in this brief sketch.

I first met Dr. Jeffries in 1918 in Cleveland. As a consultant for the lamp division of the General Electric Co. he had already pioneered the scientific study of tungsten. Upon publication, this work displayed so much originality in thought and execution that it excited the admiration of fellow scientists; in a more prosaic role it provided the control for the manufacture of tungsten wire and the processing of filaments at the lamp factories.

It was not long after this that I joined the same organization and so came more directly in contact with Dr. Jeffries. This close association revealed a pattern of human behavior that was as unusual as it was stimulating and inspiring. Among other activities he met at intervals with groups at the Wire Works or at Nela Park to discuss projects which were currently in development. I recall easily what it meant to us when the word came around prior to such a meeting that "Jeff will be there!" During the discussion of the project, data would be presented and opinions advanced, but toward the end he would always give us a masterly analysis of the problem at hand and an appraisal of what it all meant. His contributions were always interesting to a point of fascination and their effects carried over into our daily work. Somehow he always had a fund of knowledge that was truly encyclopedic which he marshalled into an array of arguments — both pro and con — that left us with no doubt as to the conclusions which could be legitimately drawn.

Management was likewise attracted by this wealth of information and clarity of thought, and the managers at Nela Park — Messrs. Terry and Tremaine — turned more and more to Jeffries for counsel. This in turn was a most profitable experience for him, since these two were master-builders of American industry. In this way Terry and Tremaine selected their young scientist-consultant, fostered his talents for finance, industry and management, and trained him for a key position in the electrical industry. Dr. Jeffries has continued in this work ever since and is now technical director of the Lamp Division of the General Electric Co. — on a full-time basis, let it be added for the sake of clarity.

Many years before, while teaching metallurgy at the Case School of Applied Science, Jeffries became director of research for the Aluminum Castings Co. of Cleveland. This appointment, and the work with General Electric just mentioned, absorbed his time; he resigned his faculty position, although, as Sauveur has so aptly expressed it, in a broader sense he has never ceased teaching. Recently he was named to the board of trustees at Case.

The work for the Aluminum Castings Co. (later the Aluminum Co. of America) has been one of the most important phases of Jeffries' career, in terms of both accomplishment and length of service. At the beginning the facilities were limited for any formal work but the tempo was fast, due to rapid expansion into the automotive field and important applications of aluminum in war work. It was not long before the need of a research laboratory was realized, and one was built from income resulting from the use of his ingenious device of a copper plug in a permanent mold to secure sound castings.

By the end of the war the duties had become so arduous at the Castings company that an assistant was needed, so the other part of the famous team of "Jeffries and Archer" was acquired. During the day they plied their trade to the benefit of aluminum alloys, but during off-hours they brought the whole field of metallurgy under review. Those productive years of the 20's deserve more than passing mention for it was the broad generalizations of this decade that placed the Science of Metals on a new and more intelligible basis.

As already noted Jeffries had previously studied the irrational tungsten and, working

for the Ph.D. under SAUVEUR at Harvard, he included the more prosaic copper and iron in these studies — as, we may presume, a valiant attempt to return to the normalcy of the day. This work was a fundamental study of the effects of temperature, grain size, and rate of deformation on mechanical behavior. The work with aluminum brought in both the newly discovered mechanism of precipitation hardening and the curious procedure of modifying the aluminum-silicon alloys. Visits to Schenectady brought in the work of HULL on the structure of metals and provided opportunity for stimulating discussions with LANGMUIR, DUSHMAN, HULL, and RUDER. At the Wire Works an X-ray machine was installed, and with ED. BAIN contributions on structure were soon forthcoming. The important phenomena of the heat treatment of steel were also studied at the Wire Works in cooperation with BILL SYKES.

All this work cut a broad swath through the field of physical metallurgy and the results issued subsequently as the exceptionally fruitful generalizations which are so well known from the 1924 book, "The Science of Metals", written with ROBERT S. ARCHER as junior author. Again we had a demonstration of an exceptional ability to organize knowledge and to express ideas with lucidity and charm — to metallurgists, executives, general audiences — yes, and to fellow travellers in a Pullman at midnight.

A distinct and highly successful chapter of Dr. JEFFRIES' career was his work in organizing and managing The Carboloy Co. It fell to my lot to make the initial demonstration which showed him the possibilities of sintered tungsten carbide tools, though perhaps it would be more correct to say that my years of association with JEFFRIES had so clearly indicated that he would make an ideal supporter of our new development that I eagerly grasped the opportunity to show him what we had. He was quick to appreciate what lay before him and was infected with great enthusiasm for its future possibilities. Here was no place for musty brains or clumsy fingers, and JEFFRIES met the challenge of the new enterprise in an able and forceful fashion. In various capacities he was now an executive planning research for the future, now a manager laying plans for a business enterprise; then a wise counselor bringing divergent viewpoints into harmony on a constructive program, and again a spokesman discussing Carboloy with the public and users. This intensely fascinating work doubtless had all the delightful qualities of an avocation. For several years now, Dr. JEFFRIES has been chairman of the board of The Carboloy Co.

Turning to his contributions to his chosen profession — it is of immediate significance to the American Society for Metals that Dr. JEFFRIES has been an active member since its founding, serving as trustee, treasurer, president, for long a member of the finance committee, and an editorial advisor to METAL PROGRESS since its foundation. In grateful recognition of these public and innumerable private services, and in view of his position in metallurgy generally, Dr. JEFFRIES' name is inscribed on the scroll of Honorary Members. Other societies have likewise enjoyed Dr. JEFFRIES' association through contributions to their publications and by many timely discussions. For these generous and unselfish contributions he has received our leading medals and awards, and is metallurgy's representative in the National Academy of Sciences, the worthy successor to this distinction of HOWE and SAUVEUR. Currently he is chairman of its Advisory Committee to the Office of Production Management on Strategic Metals.

We have come to the end of our sketch. I could discourse further on his work, his successes, and the like, but, great leader that he is, ZAY's finest influence is cast by his example. His is a living counterpart of the spirit so exquisitely depicted by GOETHE of the minstrel who, upon being presented with a golden chain for his glorious and appreciated offering, replied to the king:

> "The golden chain you may retain,
> Or give unto your vassals:
> I sing like the birds sing
> That live amidst the trees,
> The song from out my throat
> Is reward that richly recompenses."

Some of us know ZAY at his home or at his work, but many more know him through his many public addresses and appearances at technical gatherings. There, with no artificialities of delivery but with rare beauty and strength of exposition, he literally charms his audiences as he instructs them. However met, ZAY is a splendid humanitarian, a completely friendly spirit, and a benevolent guide to his fellow men. His greatest satisfaction comes from the knowledge that he has helped in life. In private or in public he gives freely of himself and his human qualities stand out for all who will perceive. He does not seek material reward, but gives because it is his spirit to give.

"QUICK, WATSON, THE MICRO!"

EXAMPLES OF METAL DETECTION

By R. M. Brick
Instructor in Metallurgy
Yale University
New Haven, Conn.

FOLLOWING the two examples of simple metallurgical detection told in the March issue of METAL PROGRESS, we now go on to consider the interesting

Case of the Checked (and Double Checked) Copper Plates

If you're planning to be married and require announcements and invitations; if you then need new Mr. & Mrs. calling cards; if you order Christmas cards with an engraved greeting; for these and countless other occasions, a flat copper plate must be obtained with the correct letters or design cut into an otherwise perfect surface. It doesn't matter if after the ceremony, the copper plate becomes a card or ash tray or meets an even less deserving fate; for the first service it performs, its surface must be free from defects.

Some heavy gage engraver's copper plates, 0.115 in. thick, that fell far short of specifications in this respect were subjected to our inquiring microscope. On one surface, deep cracks or "checks" of from ¼ in. to 1 in. long ran generally transversely to the rolling direction. The cross-section of the metal plate at two of these checks is reproduced in the polished but unetched structures of Fig. 1 and 2. The side of the sheet opposite to the intended printing surface contained a few blisters; a polished section at the end of one of these is shown in Fig. 3. A comparable good plate free from cracks showed the structure of Fig. 4 at its surface, while all plates investigated (good and bad) had an interior like Fig. 5.

Such is the evidence; how can the metallurgical detective interpret it?

The material appears to be tough pitch copper, which normally contains about 0.04% oxygen as cuprous oxide. Examination of these surfaces under darkfield illumination or polarized light changed the color of the embedded particles from gray to a brilliant ruby red — a positive identification for Cu_2O. The amount of oxide at the surface of the good sheet was about the same as in the center of all the material, and corresponded to that usually found in good tough pitch copper. The amount present on the acute angle side of the cracks in Fig. 1 and 2 is obviously much higher; it might approach even the eutectic concentration of 0.38% oxygen. The oxide-rich streaks in this region are more or less straight or bend to intersect the crack. On the low oxide side of the crack the distribution of particles indicates that the metal has flowed parallel to the crack. This observation suggests that the cracks were first formed at an early

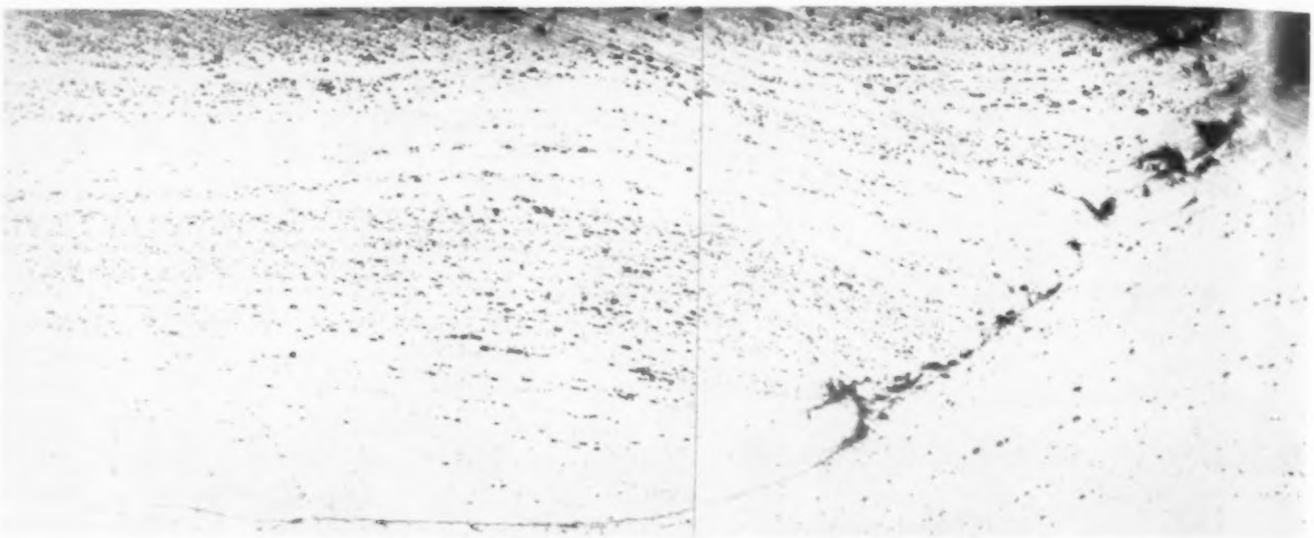


Fig. 1 — Crack in Engraver's Plate of Copper. (Section normal to the surface.) All micros unetched and magnified 150 diameters

stage in the rolling process. The depth of the oxides indicates they were present in the original ingot slab — that is, they did not originate from rolled-in scale. Finally, all cracks seemed to be associated with a plane of weakness at the discontinuity between high and low oxide areas; probably this was originally a grain boundary or dendrite boundary, although now at each crack, etching revealed new, small recrystallized grains bounded on one side by the crack.

A comprehensive survey of many specimens revealed that where a uniform, even though high, oxide content surface existed, no cracking occurred. A sudden discontinuity in the amount present, however, was invariably associated with a crack. The opposite surface which showed blisters had a structure somewhat enriched in oxides uniformly distributed. Here the cracking was internal; presumably expanding gas pressure raised blisters under the thin metal skin.

It would appear that sudden variation in oxide content, point to point in the original slab ingot, is responsible. Oxide alone is not, for oxide is a normal constituent of tough pitch copper. Most copper wire is still made from cast wire-bars with high oxide content at the top surface so that this factor alone is not responsible. Probably the small amount of hardening agent alloyed with engraver's copper increases the loss of ductility associated with the presence of cuprous oxide.

A second factor would be the overhauling or scarfing of the slabs intended to remove all oxygen-rich areas on the cast set surface. If the cutting is not quite deep enough to achieve

Fig. 2 — Another Crack. Note that there are much more oxide particles on one side

Fig. 3 — Blister, Just Below the Smooth Surface, Rather Spoils the Plate for Engraver's Use

this purpose, the surface would present a duplex condition, areas of differing ductility which would tend to separate by checking. The detective guesses that this is what occurred here.

The Case of the Streaky Nickel Silver

Metallurgists do not yet understand why metals and alloys have certain colors; why gold is yellow, copper red, and brass either yellow or red, and silver white. Mysterious was the wrought nickel silver sheet (18% Zn, 18% Ni, 64% Cu), which showed slight color variations on the buffed surface, and even more mysterious was the effect when it was electroplated with silver. Silver is not usually considered to be transparent and the plate deposit was of normal commercial thickness and probable opacity; yet the color variations or streakiness of the base metal showed through! The metallurgical problem was not to find why the streaks were still visible on the plated surface (which might be explicable on the basis of minute differences in surface levels) but the reason for the streaks on the base metal in the first place.

Fig. 4 — Acceptable Engraver's Plate of Copper Contains Normal Amount of Oxides Near Surface

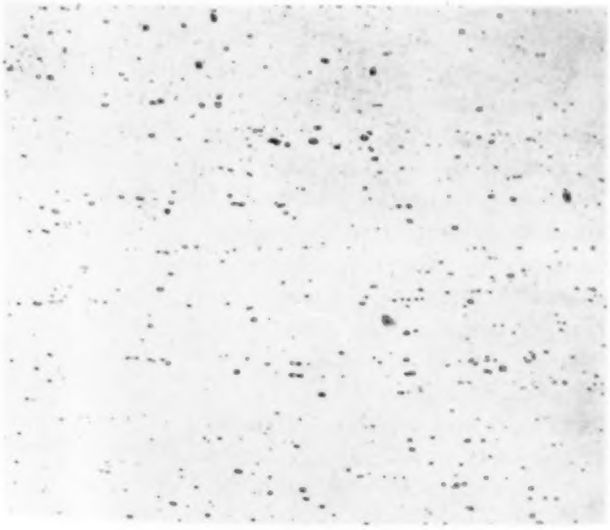


Fig. 5 — Cross-Section, Representative of Metal Near Center of All Copper Plates

A plate which had received a 50% cold reduction (by rolling) showed streaks after overhauling (surface scalping) to a depth of 0.025 in. and pickling. It was sampled for chemical analysis by milling along streaks to a depth of 0.010 in. and similarly sampling the surface between streaks. Analysis of the material showed:

Sample	Cu	Ni	Zn
Plate surface, at streaks	64.44	17.77	16.85
Plate surface, between streaks	64.39	17.94	16.50
Maximum relative error	±0.02	±0.02	±0.07

It appears that the streaks are slightly richer in the lower melting point components, copper and zinc, particularly the latter. The chemical segregation is thus of an inverse character and must have originated in the ingot. Next, an ingot was similarly sampled and analyzed with the following results:

Sample	Cu	Ni	Zn
Surface, along streaks	65.66	16.06	17.85
Surface, entire overhauling (0.010 in.)	65.18	16.64	17.70
Center of ingot	64.53	18.09	16.50

The analyses confirmed the fact that inverse segregation had occurred and gave a better idea of the extent of the chemical heterogeneity. Furthermore, this was definitely not a case of surface exudations caused by an internal gas pressure since the ingot was sound and the entire surface showed the enrichment in lower melting point constituents. It was evidently caused by interdendritic contraction sucking enriched liquid towards the surface. The degree of this type of segregation is a function of the cooling rate during solidification. Thus the cure cannot be stipulated in a few simple words; it must be sought experimentally among such variables as pouring temperature, mold temperature, and relative mass of metal and mold.

"In this case, Watson", said the metallurgical detective, "the micro wasn't useful since the alloy is a single phase, alpha solid solution. There was no marked structural variation at the streaks with the exception of a possibly less pronounced coring in these areas. That's plausible, in view of the lower nickel content of the inversely segregated material."

TABLE OF LATTICE CONSTANTS

By H. S. Rawdon
Chief, Division of Metallurgy
National Bureau of Standards
Washington, D. C.

THE TABLE of lattice constants appearing on the opposite page is one of three which were originally published in METAL PROGRESS as adaptations of data contained in WILLIAM HUME-ROTHERY's monograph on "The Structure of Metals and Alloys" published by the British Institute of Metals. An additional column has now been added which contains numbers identifying articles in the literature which are the sources of new values, and the references are listed below. In the revised tables new values have been substituted for those given formerly for 15 elements; values for 11 crystal forms not listed in the original tables have also been included.

Many of the new values in the revision were taken from the excellent tables of lattice constants compiled by M. C. NEUBURGER (reference 1). Other values were obtained from articles appearing in the literature since 1935. For some elements, different values were reported in different articles; in such cases, the values reported in the article considered best were listed. The substituted values do not represent *all* of the values obtained from re-determinations; only those which are considered better than those listed in the earlier tables of METAL PROGRESS were put in this revision.

H. C. VACHER, metallurgist of this Bureau, is responsible for this critical review of the data in recent literature, and the revisions.

References

1. M. C. Neuburger, *Z. Krist.*, vol. 93, p. 1-36, 1936.

2. W. G. Burgess and F. M. Jacobs, *Z. Krist.*, vol. 94, p. 299-300, 1936.

3. A. Jevins and M. Straumanis, *Z. physik. Chem.*, vol. B34, p. 402-3, 1936.

4. W. H. Keesom and K. W. Taconis, *Proc. Acad. Sci.*, Amsterdam, vol. 39, p. 314, 1936.

5. B. Vonnegut and B. E. Warren, *J. Am. Chem. Soc.*, vol. 58, p. 2459-61, 1936.

6. M. A. Rollier, S. B. Hendricks and Louis A. Maxwell, *J. Chem. Physics*, vol. 4, p. 648-52, 1936.

7. John T. Burwell II, *Z. Krist.*, vol. 97, p. 123-4, 1937 (in English).

8. E. A. Owen and E. W. Roberts, *Z. Krist.*, vol. 96, p. 497-98, 1937.

9. C. W. Jacob and B. E. Warren, *J. Am. Chem. Soc.*, vol. 59, p. 2588-91, 1937.

10. Endel Arnja and Harald Perlitz, *Z. Krist.*, vol. 100, p. 195-200, 1938.

11. Heinrich Bommer, *Z. anorg. allgem. Chem.*, vol. 242, p. 277-80, 1939.

12. K. Meisel, *Naturwissenschaften*, vol. 27, p. 230, 1939.

13. Harald Perlitz and Endel Arnja, *Phil. Mag.*, vol. 30, p. 55-63, 1940.

CRACKS IN FILLET WELDS

By E. Helin

(Abstract of Engineering Foundation's translation of "Sprekker i Kilsveiser og Deres Arsaker", Teknisk Ukeblad, Vol. 87, p. 289, 1940.)

CRACK-FORMING agents produced by the metallurgical processes occurring during fusion welding consist of slag inclusions, gas pockets, or shrinkage cavities, which may appear simultaneously and increase each other's effects. It cannot be definitely stated which crack-forming agent may cause a crack in any given case, but cracks are predominantly caused by slag inclusions. This is supported by the fact that welds free from slag particles are apparently crack-proof. Where the sulphur content exceeds a safe limit the sulphides formed may serve as crack-forming agents. Gas pockets occurring in the last parts to freeze assume a shape which may probably cause cracks. The study of causes is difficult because no conclusions can be drawn from the appearance and extent of the crack as to where it began or as to the location of the specific crack-forming agent.

As dissimilar electrodes and dissimilar materials produce welds with different susceptibility to cracks, these metallurgical processes and those taking place between the molten *(Cont. on p. 624)*

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery

in "The Structure of Metals and Alloys," Monograph No. 1, British Institute of Metals.

Emendations (by H.C. Vacher) represent values that have appeared in the literature from 1936 to 1940 inclusive.

Element Atomic No.	Electron Arrangemenent in Free Atoms	Crystal Structure (Note a)	Axial Ratio c÷a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter Coordination No. 12 (Note f)	Reference (g)
Group IA in Periodic Sequence										
3, Lithium	[2] 1	⧉	—	8	$3.501_{9\pm2}$	—	3.033	—	3.13	13
11, Sodium	[2][8] 1	⧉	—	8	$4.282_{0\pm5}$	—	3.708	—	3.82	10
19, Potassium	[2][8][8] 1	⧉	—	8	5.333_{5}	—	4.618	—	4.76	—
37, Rubidium	[2][8][18][8] 1	⧉	—	8	5.62±0.03 at -173°C.	—	4.87 at -173°C.	—	5.02	—
55, Cesium	[2][8][18][18][8] 1	⧉	—	8	6.05±0.03 at -173°C.	—	5.24 at -173°C.	—	5.40	—
87, Virginium	[2][8][18][32][18][8] 1	—	—	—	—	—	—	—	—	—
Group IB										
29, Copper	[2][8][18] 1	⊡	—	12	3.607_{8}	—	2.551_{1}	—	2.551	—
47, Silver	[2][8][18][18] 1	⊡	—	12	4.077_{8}	—	2.883_{5}	—	2.883	—
79, Gold	[2][8][18][32][18] 1	⊡	—	12	4.069_{9}	—	2.877_{8}	—	2.877	—
Group IIA in Periodic Sequence										
4, Beryllium	[2] 2	α=○	1.584_{8}	6,6	2.267_{9}	3.594_{2}	2.223_{5}	2.267_{9}	2.25	—
		β=○	1.52	—	7.1	10.8	—	—	—	1
12, Magnesium	[2][8] 2	○	1.6236	6,6	3.202_{2}	5.199_{1}	3.190_{0}	3.202_{2}	3.20	—
20, Calcium	[2][8][8] 2	α=⊡	—	12	5.56	—	3.93	—	3.93	—
	at 300°C.	β=?	—	—	—	—	—	—	—	1
	at 460°C.	γ=○	1.64	6,6	3.94	6.46	3.94	3.955	3.98	—
38, Strontium	[2][8][18][8] 2	⊡	—	12	6.07_{5}	—	4.29_{6}	—	4.29_{6}	—
56, Barium	[2][8][18][18][8] 2	⧉	—	8	5.01_{5}	—	4.34_{3}	—	4.48	—
88, Radium	[2][8][18][32][18][8] 2	—	—	—	—	—	—	—	—	—
Group IIB										
30, Zinc	[2][8][18] 2	○	1.8560	6,6	2.659_{0}	4.935_{1}	2.659_{0}	2.906_{1}	2.748	—
48, Cadmium	[2][8][18][18] 2	○	1.885_{9}	6,6	$2.973_{1\pm2}$	$5.606_{9\pm5}$	2.973_{1}	3.287_{2}	3.042	1
80, Mercury	[2][8][18][32][18] 2	▱	α=70°31.7′	6	2.999 at -46°C.	—	2.999	—	3.10	—
Group IIIA in Periodic Sequence										
5, Boron	[2] 3	○	—	—	—	—	—	—	—	1
13, Aluminum	[2][8] 3	⊡	—	12	$4.0414_{5\pm2}$	—	2.857_{7}	—	2.80 to 2.86 (note b)	3
21, Scandium	[2][8][9] 2	α=⊡	—	12	4.532	—	3.925	—	3.925	12
		β=○	1.585	6,6	3.30	5.23	3.23	3.30	3.26_{5}	12
39, Yttrium	[2][8][18][9] 2	○	1.588	6,6	3.66_{3}	5.81_{4}	3.59_{5}	3.66_{3}	3.62_{9}	—
57, Lanthanum	[2][8][18][18][9] 2	α=○	1.613	6,6	3.75_{4}	6.06_{3}	3.72_{7}	3.75_{4}	3.74_{1}	—
		β=⊡	—	12	5.29_{6}	—	3.74_{5}	—	3.74_{5}	—
89, Actinium	[2][8][18][32][18][9] 2	—	—	—	—	—	—	—	—	—
Group IIIB										
31, Gallium	[2][8][18] 3	▯	—	—	4.516_{7}	7.644_{8} (note c)	—	—	—	—
			a÷b÷c = 1:0.99868:1.69257,		$b=4.510_{7}$					
49, Indium	[2][8][18][18] 3	◬	1.07_{8}	4,8	$4.58_{5\pm4}$	$4.94_{1\pm5}$	4 at 3.24_{2}	8 at 3.37_{0}	3.13_{8}	1
81, Thallium	[2][8][18][32][18] 3	α=○	1.60_{0}	6,6	3.45_{0}	5.52_{0}	3.40_{4}	3.45_{0}	3.42_{7}	—
		β=⊡	—	12	4.84_{1}	—	3.42_{3}	—	3.42_{5}	—

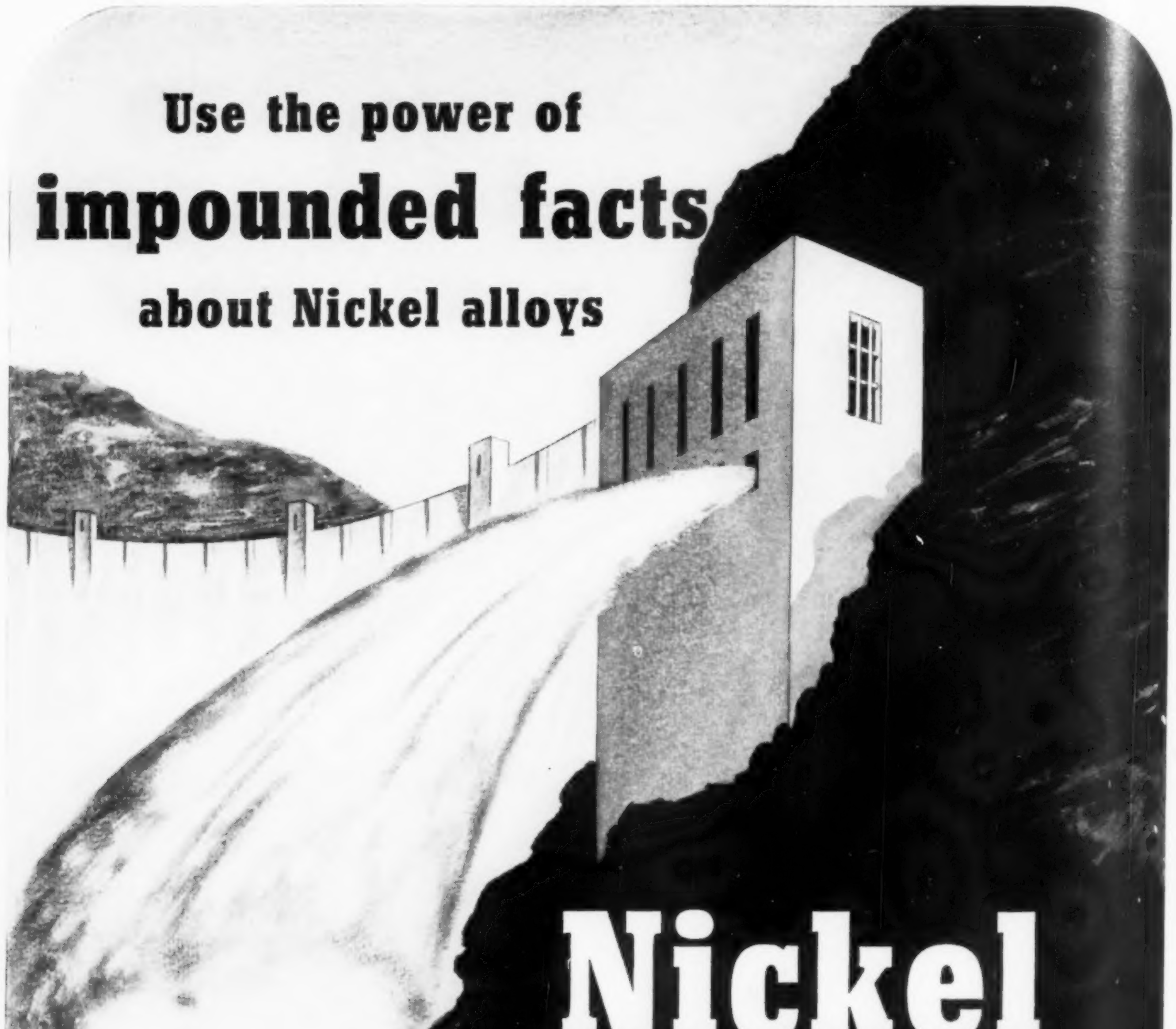
Notes: (a) ⧉ is body-centered cubic; ⊡ is face-centered cubic; ○ is close packed hexagonal; ▱ is simple rhombohedral; ▯ is orthorhombic; ◬ is face-centered tetragonal.

(b) Appears to be smaller in some alloys.

(c) 8 atoms to unit cell; each atom has 1 neighbor at 2.43_{7}, 2 at 2.70_{6}, 2 at 2.73_{6} and 2 at 2.79_{5}.

(f) Atomic diameters for new values have been computed by following Hume-Rothery's procedure whenever possible.

(g) See Page 580, Metal Progress, May 1941.


Use the power of
impounded facts
about Nickel alloys
Nickel
Time-proved answers to your questions about Nickel alloyed materials are quickly available. From information assembled through years of research and field studies, The International Nickel Company, Inc. compiled and condensed essential facts into convenient printed form.
Now... when minutes and materials have become so vital... make full use of this experience. Send for a check list of helpful printed pieces on the selection, treatment, fabrication and use of Nickel alloys, or send specific questions to:
THE INTERNATIONAL NICKEL COMPANY, INC.
67 WALL STREET
NEW YORK, N. Y.

CRITICAL POINTS

By The Editor

AFTER much preliminary arranging, was able to visit Major LESLIE FLETCHER in the strongly guarded Frankford Arsenal, where he has charge of research and control work in metallurgy, chemistry and ballistics. The last-mentioned department is most fascinating, possibly because it is most mysterious to an old-school engineer, who finds the multiplicity of electronic devices so magical. Ballistic research aims to perfect our information about the actual happenings within the gun during the explosion of the propellant, and about the flight of the projectile; thus the design and effectiveness of *materiel* can be improved. A further aim is to devise better equipment for the proof houses, so the *routine testing* of ammunition may be easier and more accurate ..... Measurement and recording of time to a millionth of a second is of fundamental importance in this work, and — according to my guide, WILLIAM KROEGER — a great advance in this respect is the use of a crystal "interrupter" that produces a pulsating current of rigidly constant frequency as long as its temperature does not change. These pulsations are counted by a clock mechanism (and checked daily by time signals from the Washington Observatory) and appropriately magnified by electron tubes; they are used with chronographs to mark time intervals on photographic films ..... In ballistics, the changes in velocity and pressure are so violent that ordinary devices cannot follow them accurately due to inertia and vibrational effects — hence modern measuring equipment substitutes the electron, of mass infinitesimal and of velocity almost infinite ..... Another discovery of prime importance is that a projectile in flight acquires a charge of static electricity; this means that the bullet can be fired through a pair of short ring-like coils at known distance apart and "kicks" a usable amount of current from each in passing. Even the slight obstruction of cutting a wire or sheets of tin foil is now avoided. ..... Usually "instantaneous" photographs are sought, but in studying armor and armor piercing bullets, a flash of light which dwells for a few millionths can record the decelleration of the bullet's base as it penetrates or shatters itself. Researches of this sort have not gone far enough to permit general conclusions to be drawn, but the endeavor is to find some correlation between the work of penetration when the bullet is pressed through the armor slowly (as in a compression testing machine) and when it is shot through violently at 2000 ft. per sec. This suggests a possible laboratory test for bullet and armor plate makers, or those interested in their improvement. (By the way, these hardened steel bullets apparently support safely a stress in compression across their body in excess of 500,000 psi. during slow pressing through armor.)

Ballistic Researches at Frankford

To GLENN L. MARTIN's rapidly expanding aircraft plant, near Baltimore, and talked with CARL HAMLIN, chief inspector, about a series of lectures on metal inspection before the Western Metal Congress and Exposition and concluded that the main problem was what to leave out of the dozens of important things that might well be discussed. CUSTIS STEPHENS, who directs about 100 men in the receipt, testing and warehousing of all incoming metals, as well as their issuance to the plant, told of the extraordinary care taken to inspect and identify *large* bars singly, whether of steel, bronze or aluminum. Anything measuring 2 in. thick or more is individually sampled, analyzed, and tested; disks from both ends of each bar are etched. No bar is put into stock until it passes such inspection; no bar is issued to the plant unless the requisition is accompanied by the drawing for the part, and receives STEPHENS' personal approval. In this way the materials supervisor checks the correct use of steel or alloy in every important new job, and thus exercises an important metallurgical control against mistaken applications. Once an airplane is put into design, most forgings are bought in quantity; prior to that time,

Sub-Visual Defects in Aluminum

important parts are hand forged to approximate shape (rather than machined from solid bar) to get a good distribution of "fiber". For such new parts the extra care noted above in preventing misapplication is especially necessary . . . . Until recently every structural casting was X-rayed for internal soundness; many small ones are grouped on a single film but even so 5000 X-ographs are made each month. About 600 of over 70,000 aluminum castings appeared of doubtful quality (0.86%, to be exact) so the Air Corps requirement has now been changed to require only one-quarter of all receipts from approved sources to be X-rayed . . . . . All steel forgings and weldings are magnafluxed. Tiny surface cracks on aluminum forgings and extrusions are evident after anodizing — the chromic acid absorbed in the defect gradually exudes a brown stain . . . . . Interested to find 18-8 corrosion resistant steel in various forms and modifications ordered by the carload, and that 16% chromium, 2% nickel steel conforming to Navy Specification M-286, heat treated to 138,000 yield and 180,000 psi. ultimate, is widely used for bolts, terminals and forged fittings requiring both high strength and corrosion resistance.

To a "Weld-formation Please" program imitating the one radio quiz program most worthy of adult minds. The experts were Fred Plummer of Hammond Iron Works, Ed Smith of Lincoln Electric Co. and Bob Kinkead, Cleveland consulting engineer, and were wittily chairmanned by George Sieger of S-M-S Corp., Detroit manufacturer of welding electrodes. There picked up the following notes about welding in defense projects:

Welding of Hulls, Armor, Aircraft

In the Navy, hulls of submarines are 100% welded, of destroyers about 75%, light cruisers from 60 to 70%, and auxiliary ships from 50 to 85%. In the Army, homogeneous armor is being welded in production while at a mild preheat below the tempering temperature. In the Air Corps, the "stored energy" principle applied to spot welding is producing welds in strong aluminum alloys that meet all requirements of Army and Navy specifications, and are ready for use on main structural members as soon as designs are changed. (At least one large commercial transport, almost rivetless, is now in successful operation.) . . . . . The Editor is informed that this "stored energy" welding also reduces the amount of aluminum picked up by the electrodes. However, operations must still be interrupted all too frequently to dress them. It seemed to him that a "typewriter ribbon" of thin copper might be placed between electrode and aluminum, moved ahead slightly after each weld, and so carry away continually any fouling particles.

Anti-Fouling Device for Electrodes

Wendell Hess, who is investigating aluminum problems at Rensselaer Polytechnic Institute for the Welding Research Committee of The Engineering Foundation, has tried the scheme and says it works. The copper should be about 0.003 in. thick, to be strong enough yet conform to the electrode easily (if too stiff an oval instead of a round spot is welded) and very smooth to avoid impressing undesirable markings into the aluminum surface. Six to eight welds in 0.040-in. duralumin can be made before the ribbon needs to be pushed free from the electrode tip by stripper rods, and notched ahead one diameter to a clean, fresh surface.

Much impressed — in this day of intemperate argument about preventive war vs. home defense, and the predictions by both sides that the future is black indeed unless the United States does so-and-so — by reading the following words of cheer from Karl T. Compton, president of Massachusetts Institute of Technology:

Who Envies Whom?

"Starting with today, we know that America is in most respects the envy of every other people on earth. Often we find fault with this or that condition in our America, but any useful judgment of America today must consider practical standards of comparison, and by comparison with any other part of the world we have sound reason to be thankful and to have faith in the future.

"Natural resources? The most varied and abundant of any nation. Comforts of life? By all physical standards — such as heated and lighted homes, silk stockings and fur coats, automobiles and refrigerators, movies and radio, medical care, and food supply — far ahead of any other people. Freedom of speech and action? Where else in the world today can you come as near to saying what you think or acting as you please — as long as you act decently — or go ahead just as far as your ability and luck will take you (even granting that situations are not perfect)?

"So I submit that America starts today in a situation that should give us real confidence in tomorrow."

IMPACT AND HARDNESS TESTS; NOTES ON THEIR PRACTICAL USE

By Gordon T. Williams
Metallurgist, Deere & Co.
Moline, Ill.

THE TENSILE and fatigue properties of steels were discussed in the first two articles of this series (March and April METAL PROGRESS) and we will now go on — more briefly — to two more tests of considerable utility in the selection of steels. But before taking up the matter of impact testing, let us revert a moment to a couple of points brought out early in these articles.

In the first place, figures for elongation and reduction of area in the tensile test will be measures of the *capacity* of the material to deform. The tensile strength and yield point indicate *ability to resist* deformation. These are opposing properties and stop us from getting what we want in the ordinary heat treated piece, such as maximum tensile strength and maximum yield point, combined with all the ductility we can get (even more than that, for "all we can get" may be very little!). Take glass — it will carry a tremendous load if properly applied, but it is impossible under ordinary conditions to apply load in such a manner. If we get the slightest bending, it gives up the ghost and breaks right then and there.

Toughness can be argued about without reaching any solution. We will all agree that lead is not a tough metal. This points out one characteristic of a definition that may be arrived at by the process of exclusion — toughness is not alone the ability to deform. You can hammer a lump of lead out into a large piece of foil, but that is not a measure of toughness. Nor is hard toolsteel usually considered tough — relative to cast manganese steel, for instance. Most of us think of toughness as the ability of something to absorb a heavy load before it bends and taking a fair bend before it breaks. In other words, a tough metal would have both high *capacity to resist* load and good *capacity to deform*.

These preliminary remarks bring me to a consideration of the Charpy or Izod impact test, commonly thought of as a means of measuring toughness. The impact test — what value has it? I suggest if you want to get an answer, you pick out your authority and side with him, because you can find eminent metallurgists who like the test and those who don't and those who take a middle ground. In general, it is agreed that the greatest use of the impact test on steel is as a uniformity test. Also variations are found that way that are not shown in other ways. However it is not an engineering test; the *figures* it gives are very close to useless to a

designer or metallurgical engineer. In my own neighborhood, GLEN REIGEL of Caterpillar Tractor Co. is certain, on the basis of service records, that gear steels having high impact values are much superior in service to gear steels having low notch bar values. However some equally responsible men, ALMEN and BOEGEHOLD of General Motors Corp. in research work reported to the American Society for Testing Materials in 1935, stated flatly that the impact test did not correlate in any way with rear axle gear life. In their opinion, gears fail from fatigue; therefore the correct procedure is to design a gear so it avoids stress concentrations by having generous areas of tooth contact and adequate fillets at the root. If that is done then numerous steels will give adequate hardness and strength, and the choice would fall to the cheapest one that will harden properly and with the least distortion.

Impact tests are made by breaking a specimen with a sudden blow. Specimens can be broken as beams, either striking their center as they are supported at the ends, or fixing in a vise and breaking off the protruding end. The former is the principle of the Charpy test; the latter of the Izod test. (Memo: we say Eye′-zod, with a long I, but the Englishman who originated the test calls himself Iz-zod, with the short vowel sound.)

Also, there is the "tension impact test" where the specimen is shaped very similar to but shorter in gage length than the ordinary tensile specimen and carries a block at its end which strikes a stop as the falling hammer carries the front end of the specimen along and fractures it on the shock.

Lastly, "torsion impact specimens" are used for hard toolsteels where the piece is broken by engaging suddenly a high velocity wheel; the flywheel velocities before impact and afterwards are noted and the energy consumed in fracture may thus be computed.

Test specimens may be broken by one blow or may be broken by repeated blows. It has usually been found that if it does not take many blows in repeated impact, the results coincide fairly well with those from ordinary single blow specimens. If it takes a lot of blows, it becomes a fatigue test.

The early form of impact test uses the blacksmith's hammer. Somewhat more refined in form, this persists in the American Railway Engineering Association's drop testing machine. A tup weighing 2000 lb. with rounded face is dropped on the center of a short piece of rail, placed head downward on supports 4 ft. apart resting in turn on a spring cushioned base weighing 10 tons. The specified height of drop depends on the weight of the rail; for instance rails weighing more than 121 lb. per yd. must withstand a 22-ft. drop of tup without fracture.

The modern impact testing machine uses a carefully prepared small specimen and breaks it off sharp. (If the specimen does not break, merely bends over, the results are not comparable.) Figure 1 is a view of one. A heavy hammer head is pivoted on a stout arm. It is released from a certain height and strikes the specimen on reaching dead center, breaks it, swings on past and rises to a height on the other side which is measured and compared with its original position. The difference is a measure of the amount of energy required to break the sample and brush the fragment aside (plus the instrumental friction).

Fig. 1 — Pendulum Type of Impact Machine at Jones & Laughlin's Development Laboratory. The Izod sample is fixed in the vise on the anvil below, and the pendulum is raised ready for the swinging blow

Samples used are various; typical ones used in America are shown in Fig. 2. The top one is for impact tension; one end is screwed into the rear of the pendulum; its other end carries a crosshead or stop which is too large to go between the standards of the machine. They strike and either stop the pendulum or break the specimen. Some testing engineers favor this type of un-notched sample because it eliminates uncertainties about the sharpness or condition of the notch. Likewise it is adaptable to impacts under high velocity, as in the ballistic studies.

The second and third represent 10-mm. square Charpy specimens. These are supported at the ends at a span of 40 mm. (1.575 in.) and struck opposite the notch on the smooth side. The one marked "Alternate Charpy Impact Specimen" is an A.S.T.M. standard, except that it should be 2⅜ in. long. A.S.T.M. standard Izod specimen is next to the bottom; the long end is fixed in the vise vertically, the notch just clearing the top of the jaws. The bottom specimen containing three notches is drawn to smaller scale; actually it also is a 10-mm. square bar.

When these pieces are broken in the prescribed way, the results (expressed as ft-lb. of energy absorbed in the work of fracture) measure a particular property, namely, the effect of a notch of certain shape on the energy absorbed by a 0.394-in. wide specimen on being broken by a quick blow. The Izod is more commonly used in this country than the Charpy, which is the European favorite. Square specimens are quite expensive to machine, but not much testing has been done on round impact specimens — they would be much cheaper to make. A three-notch specimen costs only slightly more than the single notch, and it gives three readings which may be averaged. Round specimens (0.450-in. diameter) are used in many laboratories for their own purposes, and for torsion impact tests on toolsteels. Likewise unnotched square specimens ¼ in. square and 6 in. long, broken in a Charpy fixture, have been used to study die castings, or even toolsteels, which in the hardened condition and notched would show values of 1 ft-lb. or less — below the accuracy of the reading.

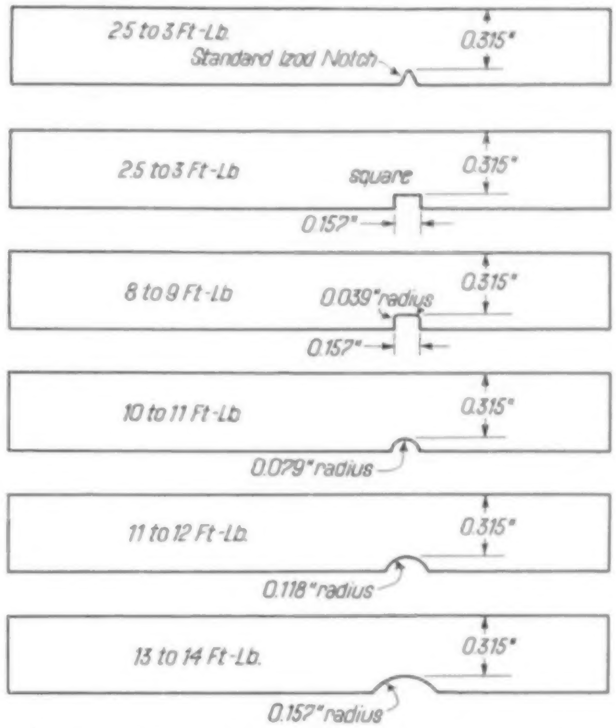


Fig. 3 — Pieces of S.A.E. 2345 (medium carbon, 3.5% nickel) — a proven steel for heavy duty — quenched and tempered to Rockwell C-55, may absorb from 2.5 to 14 ft-lb. on fracture, depending on type of notch. (From "Republic Alloy Steels")

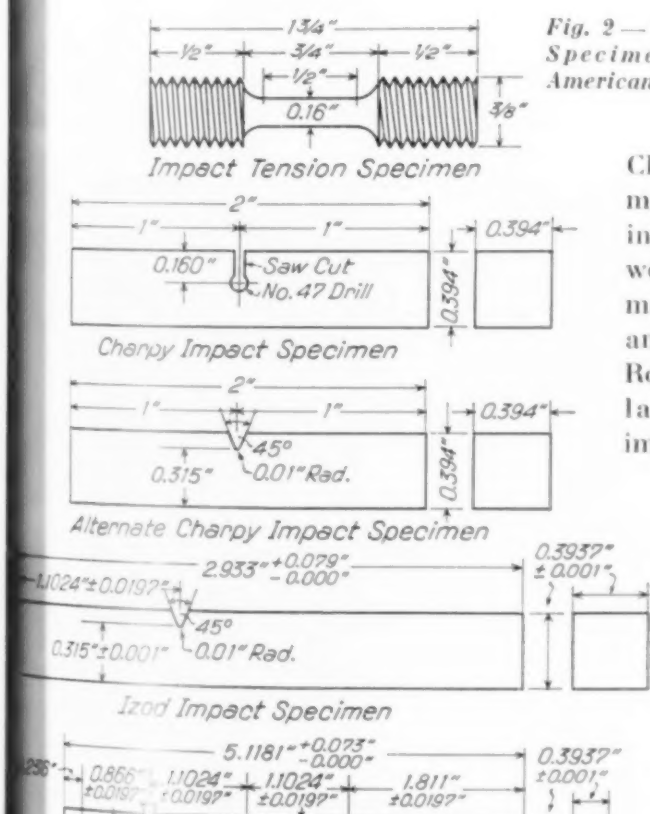


Fig. 2 — Typical Impact Specimens Used in American Laboratories

Before we make any extended remarks as to the meaning of the test, certain precautions should be noted.

First is the effect of velocity of impact. It is known that some steels appear to lose their resistance almost completely if struck with sufficiently high velocity, as by an explosion wave. However, the variations possible in the speed of a swinging

tup seem to introduce no error.

Second is the effect of temperature. This is so great that the variations in laboratory room temperature may be of importance. If 70° F. is understood, the temperature should vary no more than ± 5°. Many steels are relatively tough at summer heat, but quite brittle at sub-zero winter cold. Tests at 70° F. should then be compared with tests at −6° F., rapidly made after cooling in an ice-salt-water mixture.

Third is the shape of the notch — a most important effect, as clearly shown in Fig. 3. These impact bars are of standard cross section, made of S.A.E. 2345, fine-grained steel, hardened and drawn to Rockwell hardness of C-55. Using the regular V notch, we get readings of 2½ to 3 ft-lb. By increasing the radius at the root of the notch and finally coming to a nice full radius, we get up to 10 to 14 ft-lb. for the identical steel.

This merely emphasizes the desirability of extreme precision of shape and surface at the root of the notch. The keyhole notch (despite its less common use in America) is praiseworthy on account of the relative ease of drilling a precise hole at a precise position. Tool marks are in such a direction that they have least effect. The hole should be tightly plugged with wire during heat treatment and while sawing or grinding the slot, so that the round surface may not be changed or bruised in any way.

The greatest authority on this test is Dr. Sam Hoyt of Battelle Memorial Institute. We had him up to Cleveland Chapter to talk on this specialty, and I was introducing the speaker that night. He began by reprimanding me; when the program committee sent out the announcement, it said that he was going to talk on the impact test. "No such thing",

Fig. 4 — Sequence Showing a Pendulum Striking a Transparent Specimen of Glyptol, Photographed in Polarized Light to Show Stress Concentrations, and at a Speed of 300 per Sec. Photographs courtesy of Bell Telephone Laboratories

he said, "I will talk about the notch bar test!" So we should call it "notch bar test". Many of his ideas are contained in the article on that subject in Metals Handbook.

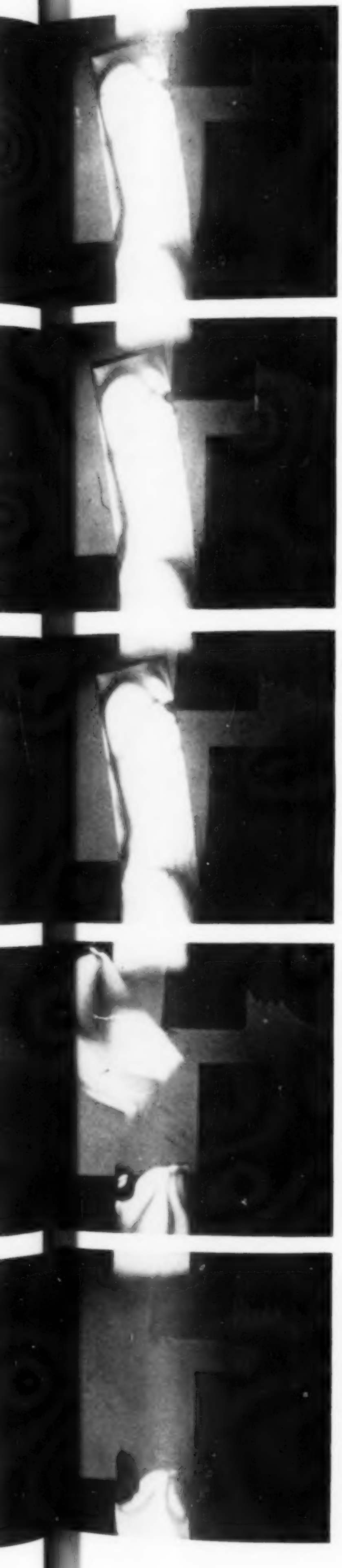
This Handbook article emphasizes what should be emphasized, namely, that the test does not measure some fundamental quality of the metal such as the cohesive strength, or even its inherent resistance to propagation of a crack, but merely the energy absorbed in breaking a sample of a steel when tested under a specific set of conditions. It may be regarded as a check test to verify the quality of a steel that gives a good account of itself in the tensile and other tests. Especially will this be true if good figures are given in more than one impact test, as for instance at 70° F. and at − 6° F. Likewise it is useful to compare results on the Izod and Charpy keyhole test bars. If the steel is tough, the Izod value will be greater than the Charpy because there is more metal to be broken; if, on the other hand, it verges on notch brittleness, the reverse will be true for the 0.01-in. radius at the bottom of the V notch is more damaging than the 1-mm. radius at the keyhole.

Another good comparison is between the standard Charpy keyhole specimen and one of double width. Theoretically the double width bar should absorb less than twice as much energy as the standard, but tough steels actually take nearly double the energy. The Handbook article gives a good example of one that did not, as follows:

Medium carbon steel forgings

were tested after two heat treatments, each giving acceptable tensile and hardness value. Both gave Charpy values of 15 ft-lb. (standard bars). When double width bars were tried, the forgings from one heat treatment gave 30 ft-lb., the other only 7 — and the latter was if anything softer and more ductile in the tension test. The former heat treatment should be used for the more severe services.

I will close this subject with the interesting movie frames of an impact test on an unnotched bar of plastic (Fig. 4) and two references to informative recent articles on subjects merely mentioned above. One is by Maxwell Gensamer in July 1940 Metal Progress on "Static Crack Strength of Metals", and it really should be read before one can get a good understanding of the early paragraphs of the Handbook article on notched bar testing. The other is by Robert Rose in April 1940, page 407, where he discusses the toughness of toolsteel and the evaluation of the torsion impact test on hard metals.



Hardness Testing

I want to speak briefly about hardness testing. My remarks can be brief because it is the commonest physical test made. Everybody knows how to do it.

Hardness — resistance to penetration — is most generally useful, although it does not tell us ordinarily what we need to know. Ordinarily we don't care to know the hardness; what we are after is a given strength and a required wear resistance. Fortunately the hardness is a very useful guide and ties right in with tensile strength. Thus, take the Brinell hardness, divide by 2, add three ciphers and you will have the tensile strength, just about. Hardness also ties in pretty well with wear resistance.

Probably few who read this can realize that some of the early meetings of the , less than 20 years ago, concentrated on the new and useful method of measuring hardness — the Brinell test. In the intervening years other equipment has been widely used. Most of it uses the Brinell principle, namely, pressing a hard accurate ball or cone into the surface to be measured.

Brinell's machine uses a 10-mm. ball, 3000-kg. load, and measures the diameter of the impression, to which the "Brinell hardness" is related. The ball used is hardened steel, and deforms slightly (or seriously) when measuring heat treated steel. Consequently tungsten carbide balls are used for hardnesses above 600.

The Rockwell machine uses a diamond point (or a small steel ball) in such a manner that the *depth* impressed by a standard load produces a dial reading.

The scleroscope is, in my opinion and experience, not very useful except where you can't use anything else. It is difficult for the untrained operator to use, but on the other hand is indispensable for use on chilled steel mill rolls and for other parts that are too hard or too brittle for penetration tests or too large to be brought to a pressure machine. It contains a diamond tipped hammer that rebounds after a fall from a certain height; the rebound is noted and reported. It measures a complex combination of properties, probably depending on the elasticity of the material.

The Vickers hardness testing machine used in aircraft industry originated in England. It is a splendid hardness test — rather sensitive, and more for laboratory or precision work than for knocking

about a test bench. It uses a small diamond impressor and the load can be selected so as to produce a square impression of the size desired, whose diagonal is measured by a microscope. It is closely related to the Brinell test.

The Monotron machine has many admirable characteristics. In it the load required to produce a given penetration is noted.

In the hands of a workman who will use it carefully, a test file is an extremely useful tool. Today there are probably more gears tested with a file than with any other instrument, because it actually tells more about wear resistance and associated characteristics than any penetration hardness test. Testing files ordinarily are hardened to about Rockwell C-65, but frequently heat treated alloy steels of lesser Rockwell hardness will resist the file. Harry McQuaid believes that file hardness is necessary for good resistance to heavy abrasive wear, irrespective of any other measurement. It is true that a steel with much retained austenite will be relatively soft to an indentation test, but file hard; in such a steel the austenite changes to martensite by pressure and high local temperature developed by friction, thus automatically hardening itself.

As a variation to the standard file test, it is very useful to take standard files and temper them to various Rockwell hardness readings by 5-point ranges all the way from C-65 down to C-25 to 30. These files, with ground sharp points, are very useful for shallow or irregular surfaces, which you can't test otherwise. If the hardness of a piece is supposed to be Rockwell C-30, you may take one of these files tempered to C-30 and trace across surface. If there are any soft spots you will find them.

The selection of the hardness test is dependent on the amount of damage which can be tolerated on the surface. If it is highly finished, we may test only a few pieces and then scrap them. How this works out is as follows: A Brinell impression on a heat treated axle 340 hard is 0.010 in. deep and ⅛ in. diameter. The Rockwell impressions for that same hardness will be about 0.005 in. deep and about 0.010 in. diameter. The "Superficial" Rockwell is a light load instrument designed for thinner pieces or very hard materials; the depth of its impression will be about 0.002 in. and its diameter 0.003 or 0.004 in.

Everyone should know that the impression must not be deeper than one tenth the thickness of the part being tested, else you'll get the "anvil effect". The heavily loaded Brinell tests should be limited to pieces ½ in. thick or thicker. On the other hand, material like cast iron with a complex structure including large flakes of graphite, should be tested with a pene-

Fig. 5 — Testing the Hardness of a Forged Connecting Rod With a Monotron. Photo by Van Fisher at Steel Improvement and Forge Co., Cleveland

trator that covers a fairly large area of metal.

The testing of hardened surfaces brings up the problem of "breaking through". To illustrate this a slightly tapered wedge of steel was casehardened to a fair depth and then ground so it presented parallel sides. The test face thus gradually went through the case, showing all effects from a deep case (0.060 in.) to no case.

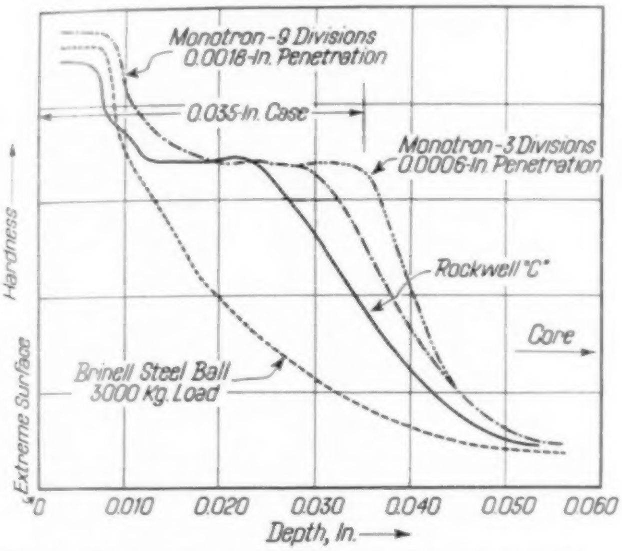


Fig. 6 — Taper-Ground Case Was Tested, Step by Step, With Different Instruments. Heavily loaded Brinell ball broke through lighter cases and indicated much softer metal than did the lightly penetrating Monotron. (Do not draw conclusions about thin and thick whole cases from such tests as above on taper ground cases)

Brinell hardness impressions were then taken as closely spaced as possible, Rockwell hardness tests similarly, Monotron readings with 0.0018 in. penetration, and finally Monotron with only three divisions (0.0006 in. penetration). Then we pro-rated the numbers from hardest case to softest core and plotted all to the same proportional scale. The result is shown in Fig. 6.

The load of 3000 kg. caused the Brinell ball to break through the lighter case depths, and so the Brinell reading indicated softer metal closer to the original surface than the hardnesses shown by the other instruments. Rockwell C-scale tests were beginning to break through at heavier cases than the Monotron, but much later than the Brinell, because of the lower load per unit of area. The Monotron with nine divisions broke through sooner than the Monotron with only three. In other words, if you want to test casehardened pieces, you must use a test that does not break through the case, else you get a combination of case and core properties.

Various steels have various properties at equal hardness. Therefore hardness does not tell the whole story. I mentioned the rough correlation between Brinell and tensile strength, and this is a very fortunate thing. There are tables available for this translation, as well as to convert Rockwell into Brinell, scleroscope into Rockwell, and so on. Fortunately on fairly uniform material, the conversion is reasonably accurate. One of the best is the data sheet, p. 428, Metal Progress for October 1940.

In conclusion, I would show in Fig. 7 a failure by "Brinelling". It is a view of a tractor transmission gear, after it had been sawed along its axis and lightly etched to show forging flow lines and depth of hardened case. It was an idler gear which runs on roller bearings on a carburized and hardened shaft. When this gear came to me for check, my first reaction was a profane ejaculation. Next I wondered how it happened. We see, by examining the photograph closely, the case was seriously worn away in the roller paths. Fortunately, the service data were fairly complete. I had a sample of the oil, and it was loaded with dirt. Here is what happened: It was a good gear, but the oil was so dirty that the bearings wore away the case to the point where the case was no longer thick enough to support the impact load, and the rollers actually hammered in!

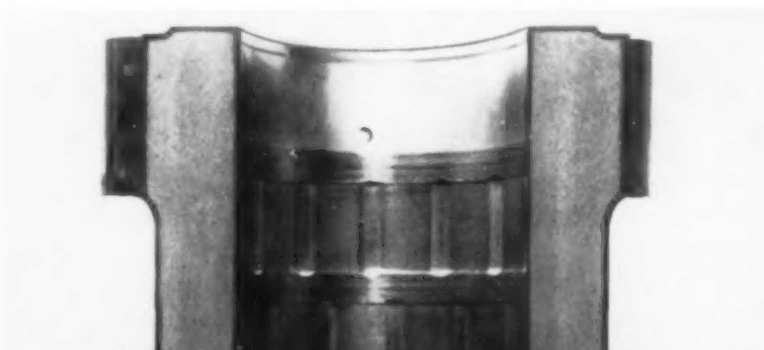


Fig. 7 — Dirty Oil Caused Excessive Wear in Roller Paths; Finally the Case Was Worn so Thin it no Longer Could Carry the Impact Loads, and the Rollers "Hammered In"

PRODUCTION OF STRATEGIC STEEL

Reported by John G. Dun
Republic Steel Corp.
Warren (Ohio) District

OPENHEARTH men look forward to the annual conference sponsored by the American Institute of Mining and Metallurgical Engineers, for it is the one time during the year when they can talk shop with a large group of men who speak their own language. The 1941 session in Chicago did not disappoint these anticipations; under the able leadership of Leo Reinartz the affair was beyond the average. Unlike the meetings held in the past, the topics centered on the vital problem of how to produce enough steel for the national defense effort and how to conserve the strategic materials used in openhearth carbon and alloy steel.

A pleasant additional feature was the announcement that the first McKune award paper was by Henry J. Forsyth on "The Role of the Ingot Mold in the Control of Semi-Finished Surface on Killed Steels". Mr. Forsyth pointed out that a good mold coating is very essential to decrease surface defects. Tar-coated molds decreased preparation cost 35% over uncoated molds. Molds tarred over 230° F. were considerably better in this respect than those cooler when coated.

Age of the mold is the largest single factor in determining the amount of surface defects produced on billet surface. Best results were obtained from molds up to about 60 pours. Beyond this, there is a gradual rise in defects until the mold is scrapped. Increase in the preparation cost at the end of the mold's life is approximately 50% over that at the beginning. Soaking pit practice is another important item. There is a gradual decrease in the preparation cost with an increase in soaking time per hour of steel held in mold.

Refractories — The drive toward increased production does not help refractory life in either furnace or ladle due to the bigger heats, larger ladles, and thick ladle bottoms. Furnace construction seemed to be of most importance, however. In order to improve roof life, a thick roof has been tried, but it is not entirely satisfactory as the checkers plug up before the maximum life of the thicker roof is reached. Medium thick, 12 to 15-in. rib roof usually appears to be most advantageous.

Insulation below the floor level has been tried and has generally been quite satisfactory. Insulation above the floor level has not been a decided improvement except to prevent infiltration of air. Insulated roofs save some fuel, but are more troublesome to repair. In some shops, where furnaces were insulated all over, about 15% fuel saving has been reported, although there was no gain in roof life or tons produced per hour.

The patented "Crespie bottom installation" deserves attention. As first originated by its inventor, it is a dolomite bottom without binder, made by mixing fine powder and coarse (rice size) dolomite, packing it in firmly under pressure to conform with the contour of the ordinary bottom. After this the furnace is heated and a smooth marble-like surface is produced, ready to be charged without any additional work. Crespie dolomite bottom was developed for European dolomite; some of our American rock can be satisfactorily used for this purpose. Following is the chemical analysis of dolomite from different sources:

	American	Italian	Belgian
MgO	36.25	38.12	56.5
CaO	57.50	54.47	56.5
Fe_2O_3 and Al_2O_3	1.00	3.25	1.5
SiO_2	1.25	2.21	0.5
Ignition loss	2.00	0.84	0.4

Lining of openhearth furnace doors with monolithic refractories means a high initial cost but is economical both of material and labor in the end because of its long serviceable life. A comparative test showed that a monolithic door lasts 12 to 13 times as long as a conventional brick lining.

In discussing the thickness of brick most suitable for the construction of openhearth furnaces, it was the consensus that 3-in. brick has

far more advantages than 2½-in. Most American plants have been using 3-in. brick during the past five years.

A comfortable ending of the refractory discussion was the brick manufacturers' comment that they had increased their capacity 25% in 1939, and another 50% in 1940, so that they feel there will be no shortage of refractories and chrome ore to meet the peak production of 90 million tons of steel per year.

Conservation of Manganese

A discussion of the strategic metal manganese was led by CHARLES H. HERTY. He pointed out that the consumer has an important role, for he must accept a lower manganese content in his steel. Over-all consumption in the steel industry is 12½ lb. of manganese per ton of steel produced, but a larger proportion is consumed in sheet steels which specify 0.30 to 0.50% Mn than in alloy grades which specify manganese up to 1.30%. Therefore a five-point drop in the manganese specification for sheet products will decrease the national consumption 2 to 3%.

Spiegel or silico-manganese instead of ferromanganese is unsuitable for rimming steel grades under 0.15% carbon, but it is for higher carbon killed or semi-killed grades. Spiegel can be added in the furnace in order to raise the residual manganese, thereby decreasing the ferromanganese addition to the ladle. In this practice the temperature of the bath should be a little hotter and the steel has to be in the furnace longer than when using ferros; specific details must be adjusted to suit local conditions. Ferromanganese can also be saved by adding as much as possible in the ladle and as little as possible in the furnace; in some shops 5 to 7% better recovery resulted from this change in practice. The amount of ladle addition can be increased to the point where the ladle analysis begins to show irregularity in manganese.

The use of high manganese pig iron is helpful in producing high residual manganese, but the residual manganese depends a great deal upon the condition and volume of the slag. One cannot cut the slag volume too much when making high carbon steel because of the danger of phosphorus reversion. High manganese rail scrap can be used in place of spiegel; however, this is seldom available, for scrap rails have a high value for re-rolling and for cupola melting into high test cast irons.

Chromium Availability

Several companies have experimented with Chrome-X and their recoveries were very favorable. As noted in METAL PROGRESS "Critical Points" in June 1940, this is a mixture of calcium, chromium and iron oxides, briquetted with silicon metal in such proportions that the substance starts a silico-thermic reaction when thrown into the furnace or ladle, and generates within itself enough heat to melt the resulting chromium and iron and the calcium silicate slag. Some users recovered 96 to 97% of the chromium by placing it at the bottom of the ladle. It appears, therefore, that Chrome-X can be substituted successfully for 60 to 65% ferrochromium. Since we apparently have enough chrome ore to manufacture it, there should be no fear for the shortage of chromium for the ordinary alloy steels. Quite a variation was reported for the recovery of carbon from Chrome-X, the figures being from 0.06 to 0.12% carbon for every per cent of chromium recovered, depending entirely on the grade of steel and local conditions.

High Iron on the Charge

The outlook for sufficient tonnage of good melting scrap is not promising. Replacing scrap with hot metal will increase production by decreasing the time out for charging. However, more hot metal naturally increases the total silicon charged in the heat; part of this excess is flushed off by charging ore with the scrap. This will avoid excessive limestone charges which slow down the heat.

In this connection an interesting talk was given by P. R. NICHOLS and J. R. BRADY on "Desiliconization of Basic Pig Iron by Roll Scale and Its Utilization in the Openhearth". Roll scale was added in runner and in ladle to about 75 lb. per ton of hot metal. Analysis before treatment was in a range of 0.80 to 1.20% Si, 1.50 to 2.00% Mn. After treatment there was 45% decrease in silicon and 35% drop in manganese. Approximately 56% of the metal in the roll scale went into hot metal which represented about 1.8% increase in yield. The temperature of the hot metal treated does not seem to change much, but the original temperature should be close to 2750° F. — at least above 2650°.

By using such desiliconized hot metal in the openhearth, the limestone charge can be reduced from 6.0% to 3.5% with the corresponding

decrease in slag volume. Time of heat was also decreased on the average about 1.25 hr. and the tons per hr. increased from 9.3 to 10.0. Although there was a high drop in manganese (from about 1.75 to 1.10%) there was only a 0.04% drop in residual manganese, and the quality of the steel is entirely satisfactory.

In discussing the conservation of hot metal temperature between blast furnace and openhearth, most were of the opinion that a mixer car has a considerable advantage over open top ladles. Some measurements showed approximately 100° F. saving in temperature during transfer.

Operations and Operators

A large proportion of our steel is produced with 1930 equipment. Well-planned operation, repair schedules and improvement in details bring a maximum return with the least waste. Since the scrap situation is becoming worse, charging must be improved in order to boost production. One shop, with 100,000 tons monthly capacity in 15 furnaces, increased actual production from 98,000 tons to 125,000 tons by doubling the size of the charging boxes (from 20 to 40 cu.ft.) and installing a faster and stronger charging machine. The improvement was due to eliminating congestion on the charging floor and cutting the charging time. In another shop, bundling of sheet scrap reduced transportation hazards and charging time.

Use of blown metal also increases production; in one case the use of 16 to 32% blown metal increased production 18 to 28% — 1% for each per cent of scrap replaced. Successful duplexing of converters with openhearths requires a rather special plant layout and rapid transfer of blown steel, else the advantages are lost through delays in one shop or the other. Under certain combinations of supply and price it may become economical for some idle bessemer departments to resume, and to cast small ingots, later to be used as heavy melting scrap.

Another item of importance is the training of personnel. A rapid expansion in steel production has made it necessary to train first helpers, particularly where the furnaces are equipped with central instrument panels. It was found that the maximum benefit from these instruments cannot be obtained until the operators understand thoroughly how to handle this equipment. In one shop the applicants for first helper are examined to reveal their ability to grasp the problems of openhearth operation and construction. After passing this examination, they are given a three months' training period under an able first helper.

Problems of Quality Control

Slag control was again a subject for lively discussion. All present agreed on the benefits to be derived from slag control on quality as well as on economy as related to the conservation of alloy and decreased rejections.

Temperature control in the openhearth is still an art. Some have tried a photo-electric cell sighted on a tube-end which is submerged in a bath, but this device is still in the experimental stage. However, each shop has its own idea of "hot" or "cold" to indicate relative temperature. The following are usually considered to be most suitable for each grade: *(a)* For killed steel, "Hot" — mainly to eliminate inclusions; *(b)* for semi-killed steel, "Medium Hot", or skulling point; *(c)* for rimming steel, "On the Hot Side", but not too hot to interfere with rimming action.

The quality restrictions placed on rimming steel for deep drawing uses are:

1. Avoid ore heats or heats with flush-off slag.
2. Avoid soft heats or late hot metal.
3. Avoid low oxide slag.
4. Last ore not closer than within 1 hr. of tapping — or even within 2 hr. Heats with bottom boil are generally avoided.
5. Residual manganese is satisfactory within 0.07 to 0.15%.

Manufacture of Shell Steels

In the manufacture of shell steels, the following points appeared to be most important and were adhered to by most of the manufacturers:

1. Hot metal charge is approximately 45%.
2. Good scrap is used, avoiding metal containing copper, tin and nickel.
3. Limestone charge is 8 to 10%; additional lime during the lime boil, if necessary.
4. Silico-manganese or spiegel and ferromanganese is used in the furnace; sometimes one third of the aluminum is added in the furnace.
5. Lime-silica ratio is from 2.4 to 2.7 (2.0 min.); FeO 12 to 15%.
6. Aluminum addition is governed by grain size, but as a rule shell steel demands large grain to improve machinability.
7. Pour in big-end-up, hot top molds. Hold 1 to 2 hr. after pour.

PERSONALS

C. H. Lage, member of the Executive Committee, Peoria Chapter, has resigned as superintendent of the mechanical division of the tractor planning department, Caterpillar Tractor Co., to accept a position with the Davis Thompson Machine Co., Milwaukee.

John R. Kildsig has left Youngstown Sheet & Tube Co. to accept a position as laboratory assistant in the metallurgical department of the Allison Engine Div., General Motors Corp., Indianapolis, Ind.

Peter L. Calamari, formerly with the War Department, has been appointed testing surveyor with the American Bureau of Shipping in Cleveland.

Major **Fred M. Reiter**, formerly industrial gas engineer, Dayton Power & Light Co. and past secretary of the Dayton Chapter, has concluded the course of instruction in the Army Industrial College in Washington, D. C., and has been assigned to duty in the Pittsburgh Chemical Warfare Procurement District.

Transferred by North American Mfg. Co., Cleveland: **H. C. Beik** to the Chicago office as sales engineer.

F. Scott Laycock, formerly with Michigan Steel Casting Co. in Houston and Spokane, is now superintendent of foundry, Walla Walla Machine & Foundry Corp.

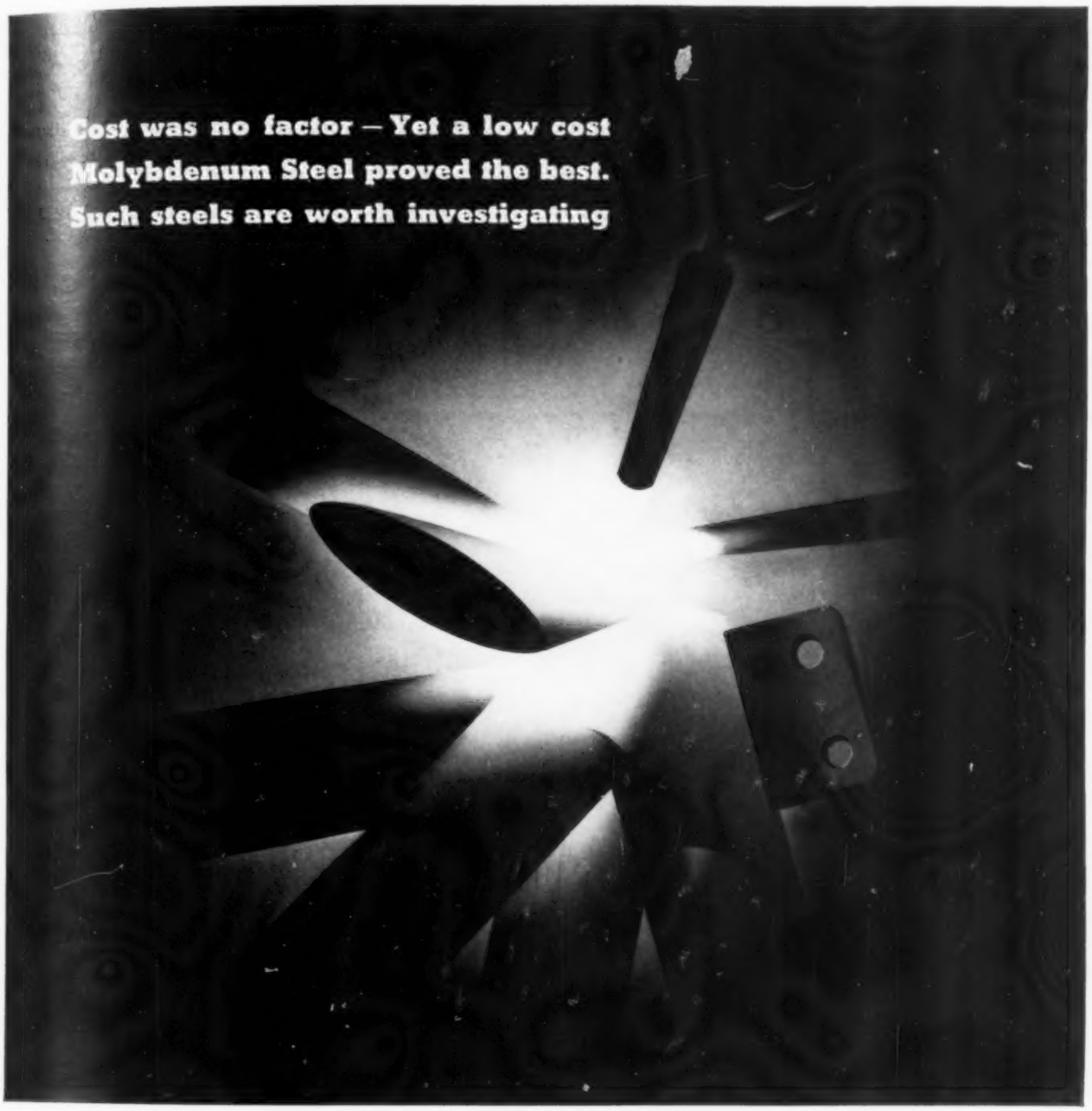
Charles E. Lynch, formerly chief inspector of Crucible Steel Casting Co., is now in the machine shop of West Steel Casting Co., Cleveland.

T. L. Haines, formerly Chicago district manager for Wm. Jessop & Sons, is now salesman in the Chicago office of Vascoloy-Ramet Corp.

Gordon Wheeler, formerly of Wellesley, Mass., has been appointed sales manager of the Sentry Co., Foxboro, Mass.

Additions to the staff of General Alloys Co., Boston: **Roger Sutton**, director of engineering and metallurgy, formerly metallurgist for the Chrysler Corp.; **Roger D. Carver,** superintendent, formerly superintendent steel foundry, Ross-Meehan Foundries; **L. M. Lindsey,** engineering sales manager, formerly with Surface Combustion Corp. **Hal G. Chase**, assistant to the president, has come into the Boston office from his western territory to help out with the defense program.

W. J. Jeffries has resigned as senior material engineer, Bureau of Ships, Navy Department, Washington, to become chief inspector of Philadelphia Ordnance District, U. S. Army.



High stresses and severe weight limitations make material specifications for airplane structural parts and fittings exceedingly strict — which explains the wide use of Chromium-Molybdenum (SAE X4130) steel.

This steel has an excellent strength-weight ratio and good fatigue strength. It is weldable by any process and welded parts can be used without subsequent heat treatment if necessary.

Write for our free publication, "Molybdenum in Steel" for complete technical information.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.
MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • CALCIUM MOLYBDATE

MOLY

Climax Mo-lyb-den-um Company
500 Fifth Avenue · New York City

PERSONALS

A. J. Carruthers, secretary-treasurer Springfield Chapter, formerly supervising engineer, Merchandise Engineering Laboratories, Westinghouse Electric & Mfg. Co., East Springfield Works, is now research engineer, Greenfield Tap & Die Corp., Greenfield, Mass.

S. I. Gleason, formerly with Menasco Mfg. Corp., is now metallurgist for Century Metalcraft Mfg. Corp., Los Angeles.

R. S. Marthens, formerly manager of the Westinghouse Gearing Division, has been appointed staff assistant to the manager of the Canton Ordnance Division.

Appointed by Lincoln Electric Co.: **B. J. Brugge**, formerly in the Houston, Texas, office, as welding consultant and engineer at Washington, D. C.

Karl Wentzel has transferred from the metallurgical division, U. S. Bureau of Mines, to the Naval Aircraft Factory in Philadelphia as metallurgist.

Edwin M. Sherwood, formerly a fellow of Battelle Memorial Institute, is at present an instructor in the department of physics at Oberlin College.

Promoted by American Brake Shoe and Foundry Co.: **John A. Fellows**, from foundry metallurgist, American Manganese Steel Division, Chicago Heights, Ill., to assistant chief metallurgist in the metallurgical department at Mahwah, N. J.

Transferred by Allegheny Ludlum Steel Corp.: **Wm. F. Barrett, Jr.**, from the metallurgical laboratory in the Dunkirk mill to the sales department in the Watervliet mill.

Added to the faculty handling the research program on physical chemistry of steel making headed by **Gerhard Derge** at the Department of metallurgical engineering, Carnegie Institute of Technology: **Allan E. Martin**, recently of the University of Minnesota, and **Karl L. Fetters**, D.Sc. Massachusetts Institute of Technology, 1940.

Frederick H. Dill has been appointed welding engineer for American Bridge Co., with headquarters at Ambridge, Pa.

Matthew M. Townsend, formerly superintendent of melting, Crucible Steel Co. of America, Atha Works, Harrison, N. J., has been made general superintendent of Copperweld Steel Co., Warren, Ohio.

Harold W. Schmid, Houston manager for General Metals Corp., has been elected a vice-president of the Corporation.

FATIGUE DATA USED IN DESIGN*

By E. C. Hartmann and R. L. Templin

THE DESIGN of almost all strength members is based primarily on the supposed static loads. When a member is to be subjected to many cycles of repeated load in service, however, there is no easy method of reducing the design problem to one of simple static loading.

Fatigue test results can be misused by applying them to designs where the conditions of the test do not fit the service conditions. Some of the factors to be considered when designing important members are:

1. Stress range considered.
2. Number of cycles.
3. Condition of the surface.
4. Influence of holes, notches, re-entrant corners, and other points of stress concentration.
5. Effect of plastic action at stresses above the elastic range.

It is important that the fatigue data used be acquired in a stress range reasonably close to that which the member being designed will carry. Data for stress ranges other than for complete reversal are usually obtained in some form of direct tension-compression fatigue testing machine, one type of which is described in the article above mentioned by R. L. TEMPLIN. Although such data are not readily available for all engineering materials, certain relations between the fatigue strengths for various stress ranges have been established, and may be used to approximate the fatigue strengths of metals for stress ranges other than complete reversal, and so an estimate may be made if fatigue tests, as of a bending beam in complete reversal, are available.

If fatigue curves are available, it is a simple matter to select the fatigue strength corresponding to any desired number of cycles. When only the endurance limit is quoted, however, it is difficult to estimate the fatigue strength at any smaller number of cycles. The only cycles which should be counted, ordinarily, are those at stresses closely approaching the maximum for which the member is designed.

Scratches, nicks, mill scale, and other surface imperfections

(Continued on page 606)

*Abstracted from two articles: "Fatigue Test Results, Their Use in Design Calculations", by E. C. Hartmann, *Product Engineering*, Feb. 1941, and "Fatigue Machines for Testing Structural Units", by R. L. Templin, *Proceedings*, American Society for Testing Materials, Vol. 39, 1939.


TAYLOR
TAYLOR
P B
SILLIMANITE

FATIGUE DATA

(Continued from page 604)

reduce the fatigue strength of the metal appreciably and some allowance for this should always be made in actual design problems. The endurance limit of mild steel is reduced at least 10% simply by leaving the mill scale on the surface.

Stress concentrations at holes, re-entrant corners and other discontinuities of section can be taken into account in several ways. One way is to treat them as if they reduced the fatigue strength of the material, and to try to find a reduction factor by reference to published data. This method is likely to lead to rather large errors because one is tempted to generalize too much about the effect of different types of discontinuities on fatigue strength, and also overlook the fact that a reduction factor applicable in one range of cycles may not apply in another range.

Another method is to evaluate the magnitude of the maximum stress at the point of stress concentration, and use this value rather than the nominal calculated stress in the fatigue analysis of the member. In certain limited cases, this method can be used with suitable fatigue strength curves for the metal to determine the life of strength members. When plastic deformation or yielding is highly localized at points of maximum stress, it reduces the intensity of the loading at this dangerous spot appreciably below what it would have been if the metal had acted in an elastic manner.

For this reason the use of theoretical stress concentration factors is unlikely to predict the fatigue strength of members built of materials with low yield strength, unless some means is found to correct the factors when the maximum stresses exceed the elastic range.

Tests have shown that where ductile metals are involved, the ultimate load on the specimen can be predicted fairly closely by multiplying the net area by the tensile strength of the material. In effect, this means that the stress concentration factor approaches unity as the maximum stress approaches the tensile strength of the ductile material. This fact becomes the basis for the proposed empirical method of modifying stress concentration factors to take into account plastic deformation — as follows: The normal stress concentration factor is plotted as a horizontal line for stresses from zero to three quarters of the yield strength of the material. At this point a straight line is drawn sloping downward to the right so that it passes

(Continued on page 612)


Two single ended, hearth type forced circulation heating furnaces for annealing copper and copper strips.
THE ELECTRIC FURNACE COMPANY
SPENCER
SPENCER
MELTING AND HEAT TREATING
From melting to bright annealing, non-ferrous metal production has been greatly improved and speeded up in the past decade by the manufacturers of oil- and gas-fired furnaces and ovens.
Today you will find a size and type for large tonnages as well as small items—for complete or semi-atmospheric control and for automatic or hand feed.
You can speed up and improve your production, reduce rejects and cut costs, and most likely cut the floor space required for heat treating by getting in touch with your furnace manufacturer.
The Spencer Turbo-Compressor Data Book will help you calculate the air supply.
SPENCER
Heating and annealing furnace for copper and brass slabs, with automatic feed table and walking beam conveyor.
SURFACE COMBUSTION CORPORATION
SPENCER
Copper
Brass
Bronze
Rockwell pot type, bronze annealing furnace.
W. S. ROCKWELL COMPANY
Rockwell continuous walking beam, cake heating furnace.
W. S. ROCKWELL COMPANY
SPENCER
S-209-E
FOR
Agitation
Combustion
Exhaustion
Gas Boosters
Ventilation & Cooling
Airplane Testing
SPENCER
HARTFORD
Turbo Compressors
35 to 20,000 cu. ft.
⅓ to 300 H.P.
8 oz. to 5 lbs.
THE SPENCER TURBINE COMPANY • HARTFORD, CONNECTICUT

FATIGUE DATA

(Starts on page 604)

through the point represented by a stress concentration of unity at the tensile strength of the material. (A point three quarters of the yield strength is selected rather than the yield strength because it is well known that in many metals plastic action begins at stresses somewhat below the yield strength.) This curve is in excellent agreement with the test results so far obtained on fabricated scale-size test specimens.

Thus, it is possible to predict the fatigue strength of a given riveted joint with a fair degree of accuracy using only the fatigue strength curve for the material obtained from small cylindrical samples on standard testing machines, an approximate stress concentration factor, and an empirical method for reducing the stress concentration factor to take plastic action into account.

A more direct and generally satisfactory method of attack would seem to be by testing representative strength members in the manner described by W. M. Wilson and R. L. Templin, in which repeated load tests are made of actual joints, beams, columns, frames, and other component parts of structures. Such tests made under controlled conditions and carried out at accelerated rates but in the range of normal working loads (or slightly beyond) would result in very useful design data.

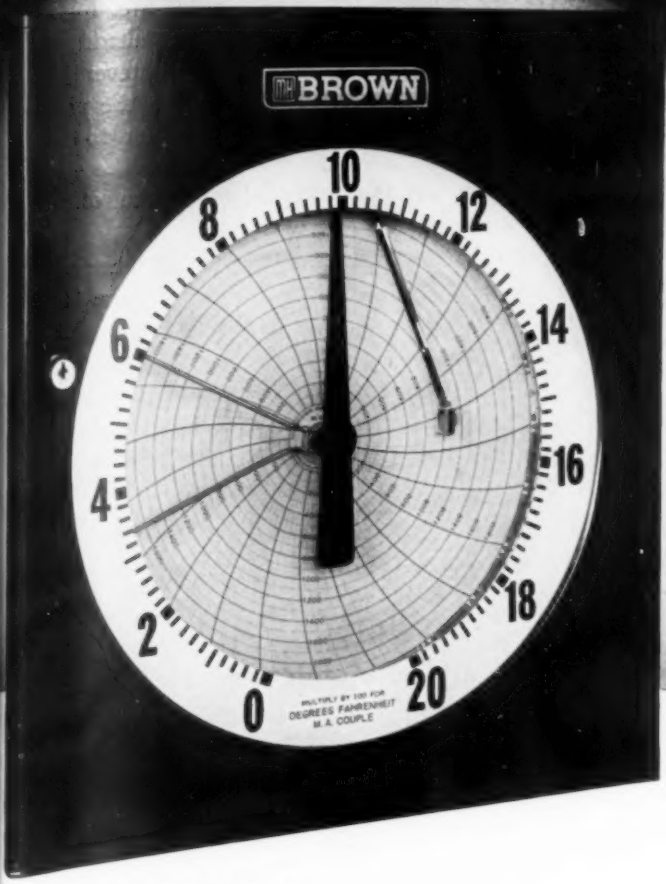
With this purpose in mind a riveted joint fatigue testing machine was designed and built early in 1935. It has a maximum capacity in tension or compression of 40,000 lb., and a speed of 312 cycles per min.

In the fall of 1935 a column fatigue testing machine was designed and built. This machine is operated at 210 cycles per min. and has a maximum capacity in tension or compression of 50,000 lb. The maximum length of specimen which can be tested is much greater than in the riveted joint machine. During the latter part of 1937 this column fatigue testing machine was modified so that it could be used for testing beams, as well as columns or frames.

While no set of experiments can cover all of the varieties of strength members with which the designer must deal, yet over a period of years such investigations will result in the accumulation of data which will guide the engineer in the selection of safe working stresses for the design of various types of members. The results of such tests will eventually show the difference between designs intended to resist repeated loads and designs intended to resist static loads.

BROWN ANNOUNCES *A New* OPERATING PRINCIPLE

IN TEMPERATURE MEASUREMENT



The New Brown Circular Chart Potentiometer
NEW OPERATING PRINCIPLE . . . .
. . . . NO GALVANOMETER

THE new, exclusive Brown "CONTINUOUS BALANCE" Power Unit replaces the conventional galvanometer . . . provides high precision . . . responds instantly to minute variations . . . maintains Continuous Balance in the measuring and recording of temperatures . . . brings to industry an advanced and practical embodiment of *electronics.*

The new Brown Circular Chart Potentiometer Pyrometer is built to withstand severe plant service . . . Its fundamental principle and simple construction make it vibration-proof . . . Wear is reduced to a minimum because there is no mechanical motion except when the temperature changes.

Interchangeable with present pyrometer installations . . . utilizes standard thermocouples and wiring.

Here is combined in one instrument . . . SENSITIVITY . . . RUGGEDNESS . . . SIMPLICITY . . . PRECISION.

For full details write The Brown Instrument Company, *a division of Minneapolis-Honeywell Regulator Co.,* 4503 Wayne Avenue, Philadelphia, Pa. Offices in all principal cities. Toronto, Canada: 117 Peter Street. . . . Amsterdam-C, Holland: Wijdesteeg 4. . . . England: Wadsworth Road, Perivale, Middlesex. . . . Stockholm, Sweden: Nybrokajen, 7.

BROWN POTENTIOMETER PYROMETERS

and

MINNEAPOLIS-HONEYWELL CONTROL SYSTEMS

To Measure and Control is to Economize

DEFENSE

(Continued from page 618)

but to meet our goal these monthly figures have to double by August and keep on doubling until the end of the year.

Thirty-caliber machine guns are close to schedule. Fifty-caliber are right up to the notch, but in the former case we are striving for a 500% increase in monthly production by the end of the year and in the latter case nearly 1000%.

The medium tank program has been deliberately held up because of the necessity of giving machine tool priority to other more critical items. Nevertheless, we will start making a few of the 26-ton tanks in April or May and are now turning out the 13-ton tanks at a fair rate. Even so, our present schedule must be doubled by January.

Small arms, such as rifles and submachine guns, are, I am happy to say, running ahead of schedule, but one can never be satisfied, for here again the production of the one has to be stepped up 100% before the end of the year and of the other about 500%.

Next to the management problem in production there is a raw material problem as well. Fortunately most of the needed products can be produced here at home. Great increases have already been effected; greater increases are under way.

The ship program presents quite a problem. Over 3400 ships, ranging from small boats and patrol craft to large tanker cargo vessels and on to battleships, are to be built. Along with this is the conversion and modification of hundreds of existing craft. All existing yards have been commandeered and seven new ones started. On the other hand, it is only a start — this program outstrips anything ever attempted as to time, volume and complexity. The urgency for speed is extreme.

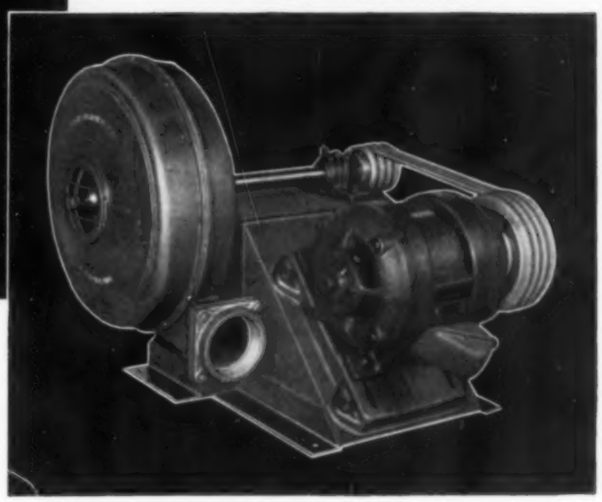
Time is the great factor. It is the one thing we never have enough of when we are well, and always too much of when we are sick. On how we use the time when we are short depends the success of our undertaking. Trains run on time against schedule. Sometimes they get away late and catch up, but they catch up only if they have a clear track and lots of steam. We got off to a late start, but we can do it, I know we can do it if we all put our hearts and our efforts into the job, engineer, manufacturer, mechanic, and clerk. This is our land — the land where democracy was really born and will live forever, so let's go full speed ahead — a green light on the track — this is "America's special," and we must all help to get it in on time.

WHEN YOU "BUY AMERICAN" BUY NORTH AMERICAN

TURBO BLOWERS
By
NORTH AMERICAN

DIRECTLY CONNECTED

V-BELT DRIVEN



SERIES 300

VOLUMES from 100 to 4,000 cu ft per min

PRESSURES from 1/2 to 2 lb per sq in

BLOWERS DELIVER FULL RATED VOLUMES FULL RATED PRESSURES	BLOWERS ARE FREE FROM VIBRATION FREE FROM BEARING TROUBLES

BLOWERS
BURNERS
REGULATORS
VALVES

NORTH AMERICAN
EQUIPMENT FOR
COMBUSTION

THE
NORTH AMERICAN
MFG. CO.
CLEVELAND,
OHIO

CRACKED WELDS

(Continued from page 580)

part and the base material during welding will consequently be the deciding factor.

The material which the base metal receives from the electrode possesses a composition, degree of purity, and temperature determined by the type of electrode used, and the drops of molten metal are more or less coated with slag. Owing to its low temperature and the minute reaction area, it is improbable that important reactions take place during the melting of that part of the base material which actually melts, between it and the gases from the arc.

When the melts from the electrode and the base material meet, a separation of the metallic and non-metallic constituents from the electrode will first take place. The slag from the coating rises to the surface and forms the slag covering. Its participation in chemical reactions, for the greater part, takes place *in* the arc. When slag and molten pool are formed, it is probable that no further interactions occur between the slag coating and the molten pool in the short time they are liquid. However it appears that the reaction products created during the mixing of electrode and base materials may be the origin of crack-forming agents. But it is more probable that they are formed later, because most of the slag emerges from the melt.

In a cold melt the primary structure consists of a great number of small crystals formed simultaneously in the melt, while in a hot melt it is built up of columnar crystals, emanating from the fusion zone and extending fanwise into the melt. A primary structure consisting of radial columnar crystals is typical of the high efficiency electrodes, while an equi-axed structure is typical of the others. A macro structure consisting of radial columnar crystals may seem inferior to an equi-axed, but the latter nevertheless is not crack-proof.

Due to the speed of the freezing, equilibrium is not obtained between solidifying metallic crystals and the melted metallic portion, but the melt will gain in carbon, phosphorus, sulphur and oxygen content — sometimes also in manganese and silicon. As a consequence reactions may be caused during the solidification of this residual mother liquor which result in non-metallic reaction products, such as slags or a gaseous product which is being precipitated before or among the crystals.

If the particles of slag are precipitated before the crystals form, the slag particles may

(Continued on page [illegible])

CRACKED WELDS

(Starts on page 580)

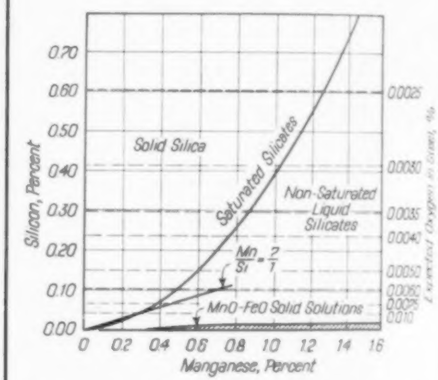
coagulate and rise to the surface. This possibility is considerably less likely if slag and metallic crystals precipitate simultaneously; then they might easily become entrapped and act as crack-forming agents.

Slag inclusions among primary crystals are to be expected in deposits rich in oxygen, and in high sulphur deposits.

It may also be remarked that if a new liquid phase is created during freezing it may act as a crack-forming agent.

From the fact that welds made with heavily coated, oxidizing electrodes are insensitive to crack formation, one may conclude that gases developed during freezing do not contribute to the formation of crack-forming agents. Cracks in fillet welds must not be considered a consequence of red shortness of the deposit, for these same oxidizing electrodes will give crack-proof deposits.

If equilibrium exists between the melt's content of alloy elements and its oxygen content, it is probable that no gas will be evolved, but that a slag phase will be precipitated. On this assumption the melt may be considered a steel melt, deoxidized with silicon and manganese, and the composition of the precipitated slag phase may be estimated, as in the attached diagram.



Types of Non-Metallic Inclusions to Be Expected in Steels, Depending on Their Silicon and Manganese Content

There exists a certain connection between the deposit's resistance to cracking and its composition; probably also the composition and qualities of the slag phase being precipitated during welding has an influence. Welds made with neutral and alloying electrodes vary in regard to freedom from cracking and silicon content, and it is possible that these two features can be correlated.

To obtain fillet welds with a maximum freedom from cracking, one must do more than use excellent electrodes. The base material must have a composition favorable to welding. How the different types of steel react in this way seems still to be an open question.

ATMOSPHERES

(Continued from page 566)

These methods of eliminating CO_2 are not basically new, but the development of specialized, ingenious equipment to make them commercially practical has so advanced that in many cases it is difficult to recognize the ancestors of some of the present equipment. Recent advances, then, have largely been the refinement and simplification of equipment based on well known reactions.

Along with the development of less reactive atmospheres has come the extension of their applications to a wider range of materials. This includes not only non-ferrous as well as ferrous metals but non-metallic materials, such as protective coatings (paints, lacquers, enamels) ceramics and foods. This is a desirable trend in approaching a widely adaptable inert protective atmosphere, and in producing equipment on a sufficiently large scale to avoid the high expense of custom-made producers.

Manufacturers of equipment generally have been alert to the troubles encountered in the past in applying controlled atmospheres. They have spent much time, effort, and money in developing equipment to give a more protective gas at lower cost. Their efforts have been particularly successful with fairly large scale equipment which is available to protect practically any hot metal, but which is relatively expensive and requires intelligent technical operation. It is therefore in the field of simpler, cheaper, small-scale equipment for the small heat treater and intermittent user that the greatest need for improvement now exists. This field is receiving attention and much of the recent equipment and that now on experimental trial is for such users.

The fact that much steel is still hardened in a partly or completely burned gas atmosphere is not due to ignorance on the part of the heat treater. He is usually well aware of the advantages of an atmosphere free of O_2, CO_2 and H_2O (and which will not deposit carbon), but all too frequently the conditions of operation and scope of his work do not warrant expensive controlled atmosphere equipment. Attempts to protect the work mechanically by a copper paint, non-metallic coatings, or similar means have been reasonably successful only under special conditions. Although effective protective coatings would be greatly welcomed, most steel heat treaters are willing to make a moderate investment in controlled atmosphere equipment and are watching with great interest the new types of simple, relatively inexpensive atmosphere producers.

PROPERTIES of QUENCHING OILS*

By J. A. Jones and W. W. Stevenson

Quenching oils may be (1) a mineral oil, (2) a fixed or fatty oil, (3) a compounded oil — usually consisting of a mineral oil base blended with varying proportions of fatty oils. Fatty oils may be *(a)* from fish and marine animals, *(b)* from land animals, *(c)* from vegetables and seeds.

The "quality" or "stability" of a mineral quenching oil may be largely summed up in its volatility, resistance to oxidation, sludging and tendency to decompose. The desired stability is attained by careful selection of the crude and attention to refining methods. All have their advantages and disadvantages in quenching baths; the straight mineral oils lose "light ends" by volatilization, whereas animal and vegetable oils oxidize. Both forms of breakdown result in ultimate inefficient quenching capability. In the present study an attempt was made to assess the relative values of the various physical properties.

The relative physical properties of commercial quenching mediums may be determined by the following tests: Saponification value, acid value, iodine value, flash point, specific gravity, viscosity, volatility, tendency to sludge, oxidation test, coking tendency, specific heat, and thermal conductivity. (The original article contains brief notes on the various methods of testing.)

In compounded oils the content of saponifiable matter indicates the amount of fatty oil present. Mineral and animal oils contain practically no free fatty acid, while vegetable oils contain only a small amount, but the content increases with time and by oxidation. The "acid value" is therefore an indication of quality and age. The "iodine value" is a measure of unsaturated aliphatic compounds, and is a means of identification of oils.

"Flash point" is the temperature at which the vapors given off by a known volume of oil ignite momentarily when brought into contact with a flame.

A low flash point indicates light fractions and the possibility of fires. The specific gravity is a clue to the origin of the oils. Viscosity determines very largely the speed with which convection currents can be set up in the quenching bath.

(Continued on page 638)

*British Iron and Steel Institute. Second Report of the Alloy Steels Research Committee, p. 269. (1939)

QUENCHES

(Continued from page 632)

Oils with large volatile fractions will show high losses in use, with automatic thickening: uniformity of quench is also affected by gas formation at the hot surface. Formation of sludge will also alter the speed of quenching.

The oxidation test indicates the tendency of an oil to thicken and to form sludge deposits. The Ramsbottom coke number gives the carbonaceous residue that may be expected on complete decomposition of the oil in the absence of air. The specific heat influences the rapidity with which an oil becomes heated by the hot steel and the thermal conductivity influences the rate of heat dissipation.

From a simple consideration of the results of chemical and physical tests made on seven commercial quenching oils, it is difficult to dogmatize in regard to their relative merits, particularly when they are being used for different purposes. However, it is possible to guess the likely behavior of those oils in service. It is obvious that very different properties are required in an oil for quenching watch springs than for an oil for dealing with heavy railway springs.

As another instance, sperm oil is excellent for heavy work, and only shows up badly in its poor resistance to oxidation, so that great care needs to be taken in keeping the liquid in the quenching tanks as cool as possible.

Loss of oil in quenching operations occurs by volatility, drip or "carry-out", and carbonization. Volatility is a function of the light fractions present, "carry-out" is connected with the viscosity, while carbonization is closely allied to resistance to oxidation. For maximum efficiency it is necessary to arrive at a compromise between the volatility and viscosity. For low carbonization the oil should contain the minimum of fatty oil or the conditions during quenching should be such as to reduce the possibilities of oxidation of the oil to a minimum.

Comparison of two used oils with samples of new oil of the same qualities indicates the changes in properties to be expected with continued use. The flash point and viscosity of the used oil are higher, the coke number, tendency to sludge and thermal conductivity are higher, the saponification value and acid value are higher, while the volatility is slightly lower than that of the new oil.

(An appendix to this original article describes in detail, with drawings, the methods used to determine the specific heat and the thermal conductivity of quenching oils.)